SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

The JOURNAL of the FEDERATION OF SEWAGE WORKS ASSOCIATIONS

Special Features

Sludge Dewatering and Disposal—Zack

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AUGUST, 1950—VOL. 22, No. 8

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TWENTY-THIRD ANNUAL MEETING

OF THE

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

IN CONJUNCTION WITH

MARYLAND-DELAWARE WATER AND SEWERAGE ASSOCIATION (SEWAGE WORKS SECTION)

AND

FEDERAL SEWAGE RESEARCH ASSOCIATION

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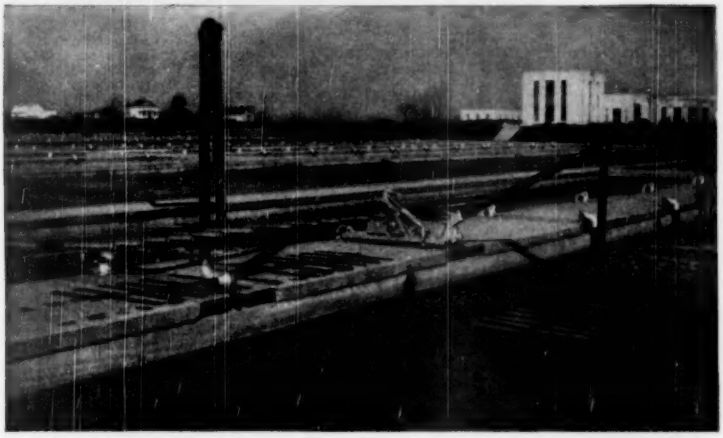

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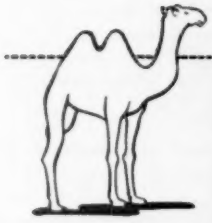

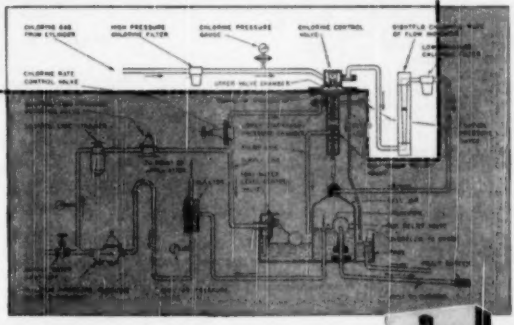

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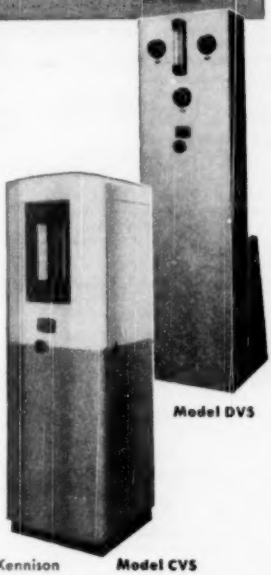

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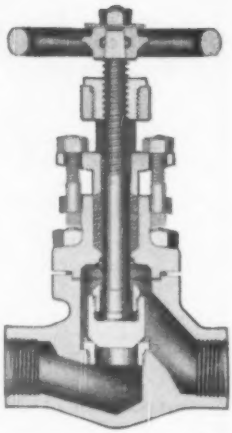

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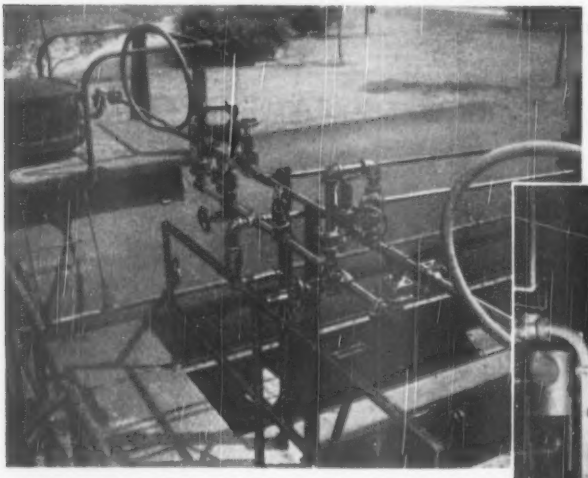

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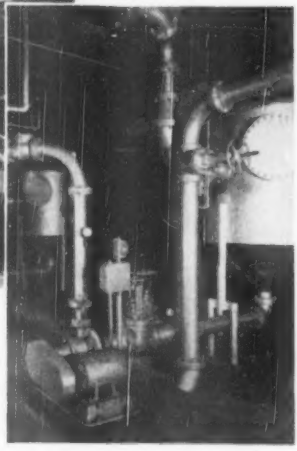

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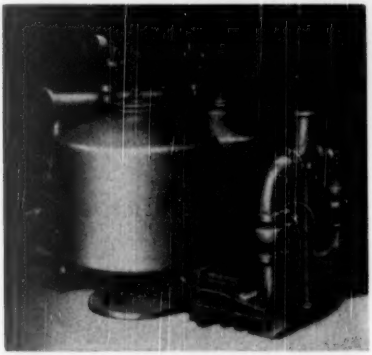

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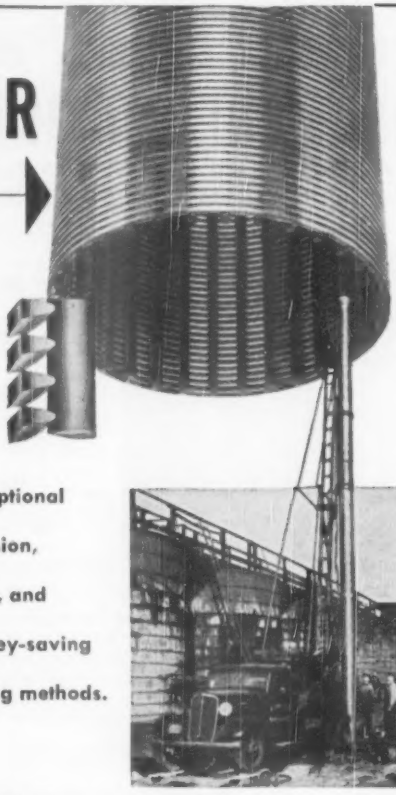

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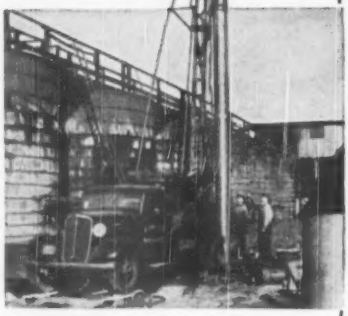

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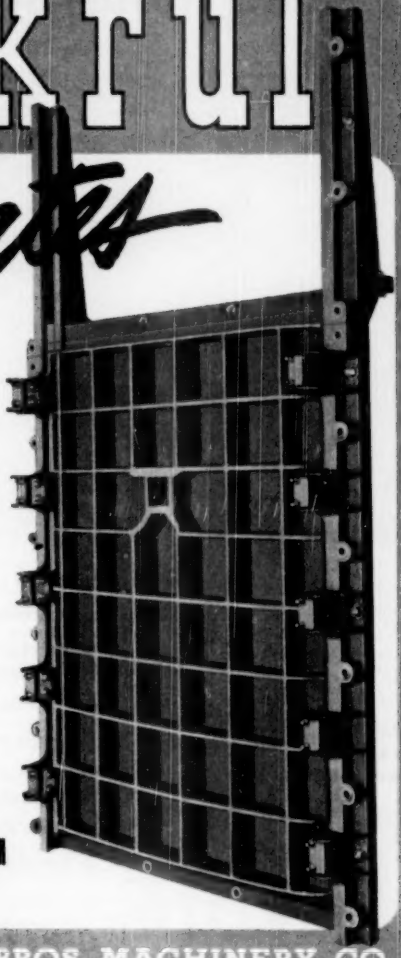

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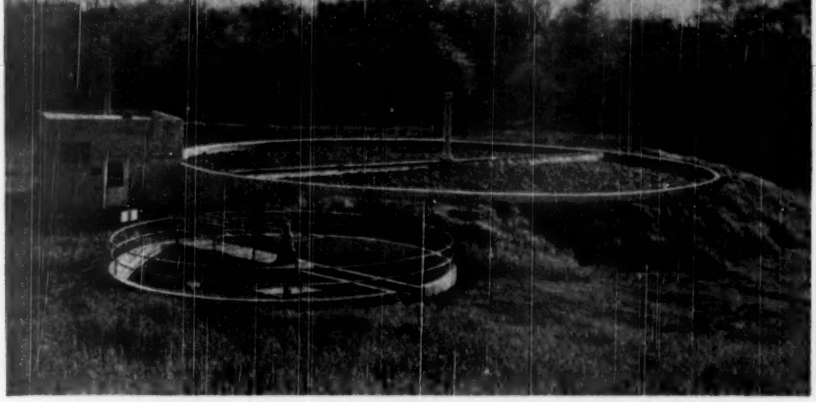

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Direct Recirculation can be easily Included in any Treatment Plant!

Biological oxidation is greatly accelerated by the Accelo Filter in the treatment of sewage and other organic wastes. This is accomplished by recirculating large quantities of the fresh unsettled trickling filter effluent directly back to the inlet of the filter distribution equipment. This method of operation eliminates many of the nuisances common to the conventional trickling filter. The ACCELO FILTER System may be used to give increased capacity to overloaded conventional trickling filters as it makes higher dosing rates possible. Other advantages include: 1. Increased biological filter efficiency, 2. No increase in size of sedimentation tanks, 3. Smaller trickling filters, 4. No clogging, sloughing or ponding, 5. No odors, 6. Reduction of psychoda fly nuisance.

WRITE FOR *complete information concerning the ACCELO FILTER SYSTEM. Ask for 12-page catalog No. 6200 containing flow diagrams, charts, installation diagrams, pictures, and interesting descriptions of its many superior advantages.*

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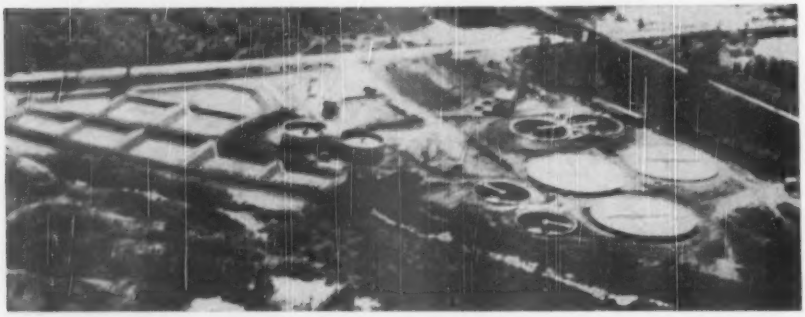
Consulting Engineer Haskins Specifies Inertol Paints throughout two new sewage plants



North Side Sewage Plant, the larger of the two plants at Joplin, Missouri.
Inertol colors and black bituminous paints applied throughout both plants.
Consulting Engineer: Charles H. Haskins, Kansas City.
Contractor for North Side Plant: Eby Construction Company, Wichita.
Contractor for South Side Plant: Lippert Brothers, Oklahoma City.

Stringent paint specifications for both Joplin plants

Exterior steel and equipment exposed to fumes: "Rustinhibitive Primer and Ramuc Utility Enamel as manufactured by Inertol Co., Inc. or approved equal." Exposed interior piping: "Rustinhibitive Primer and . . . a tough high-gloss protective enamel similar and fully equal to Inertol Glamortex." Concrete ceilings, upper walls, dadoes, floors: "Ramuc Utility Enamel or approved equal." Concrete and steel submerged in sewage: "approved acid-resistant paint similar and fully equal to Inertol Standard and Inertol Standard Thick respectively."

For exposed surfaces, the engineer chose the colors Battleship Grey, Dark Green, White and Medium Grey. For submerged surfaces, Black.

Why specify Inertol coatings?

Specify Inertol to satisfy clients and eliminate complaints on the paint job. Since Inertol chemists employ tough, chemical-resistant resins and pigments, the finished coatings stand up to abrasion, fumes, condensation and submersion. No peeling, no blistering, no fading. Inertol paints enduringly beautify and protect sewage plants.

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forever seated

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AUTOMATIC LUBRICATION WITH HYPERMATIC

EASY OPERATION — *quarter-turn to close*

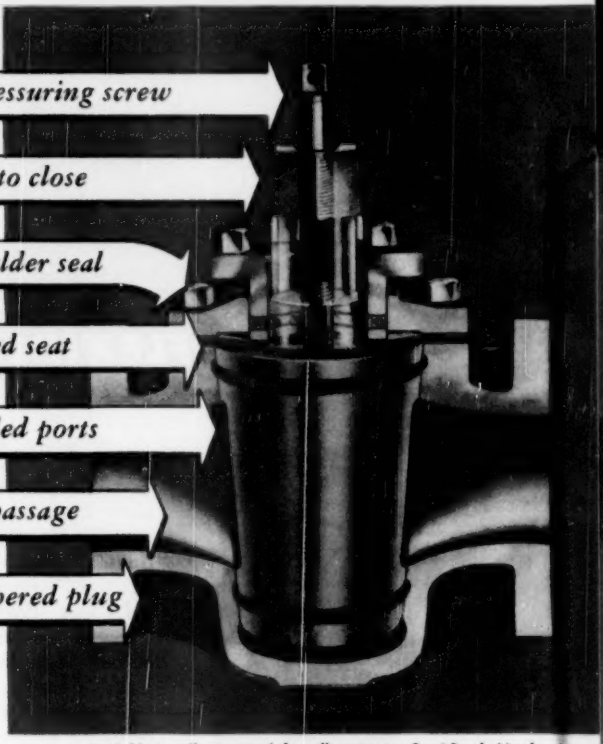
ANTI-FRICTION — *resilient shoulder seal*

UNEXPOSED — *fully-protected seat*

NON-LEAKING — *lubricant-sealed ports*

FLUSH WALLS — *streamlined passage*

NON-STICKING — *full-seated tapered plug*



Conventional valves have to unseat to open. Nordstrom valves never unseat. The plug turns on an unexposed seat. Abrasives cannot intrude to cut the seat. Result? Longest life. Positive closure.

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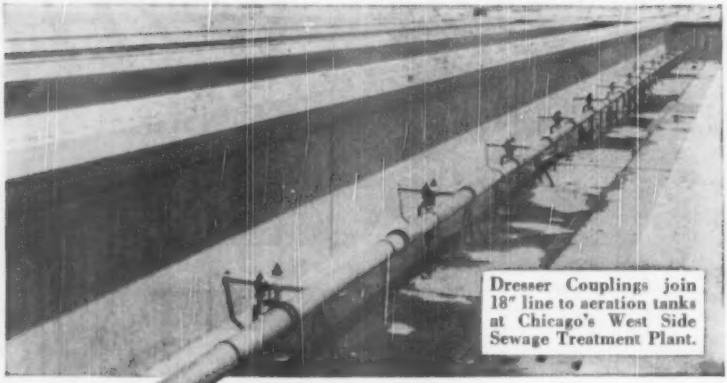

Dresser Couplings join 18" line to aeration tanks at Chicago's West Side Sewage Treatment Plant.

it pays to join air lines
FLEXIBLE-TIGHT

Fourteen years of trouble-free service in Chicago's West Side Sewage Treatment Plant prove the dependability of Dresser Couplings for air distribution lines. These lines are continuing to give excellent service.

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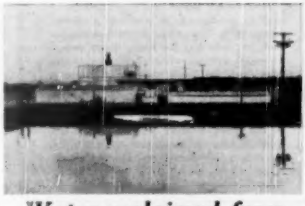
Typical Installation of
THE PROCESS OXIDATOR

General view of Bio-Oxidation plant at Hemet, California. Designed for population of 7800. Has two 40 ft. dia. Oxidators arranged for single or dual stage bio-oxidation. Ralph S. Brooks and James G. Carwile, Consulting Engineers. Karl P. Teget, Contractor.

Primary Oxidator
(Note skimming device)

Secondary Oxidator



Water reclaimed from sewage is used for irrigation

Announcement!

Process Engineers Incorporated are pleased to announce the appointment of the Pacific Flush-Tank Company as representatives for

THE PROCESS OXIDATOR

With first hand information readily available regardless of locale, every engineer interested in modern sanitation should investigate this revolutionary one tank combination aeration, coagulation and sedimentation process. As exclusive Eastern and Middle Western agents for the Process Oxidator, "P.F.T." have again demonstrated the progressive attitude that has marked their continual advancement in the field of sewage treatment since 1893. Process Engineers Incorporated will continue to service demands for the Process Oxidator in the West where installation after installation has resulted in lower initial expenditures and higher removals at a greatly reduced cost per PPM removed.

The Pacific Flush-Tank Company and Process Engineers Incorporated have available Bulletin 106 which gives full information about this new leader in sewage treatment. Both firms also maintain a staff of specialized Engineers who will be glad to assist you with your particular problem.

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No pipe that is provably deficient in any of these strength factors should ever be laid in city streets

CRUSHING STRENGTH — The ability of cast iron pipe to withstand external loads imposed by heavy fill and unusual traffic loads is proved by the Ring Compression Test. Standard 6-inch cast iron pipe withstands a crushing weight of more than 14,000 lbs. per foot.

BEAM STRENGTH — When cast iron pipe is subjected to beam stress caused by soil settlement, or disturbance of soil by other utilities, or resting on an obstruction, tests prove that standard 6-inch cast iron pipe in 10-foot span sustains a load of 13,000 lbs.

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Without crushing strength—or, for that matter—without all of the strength factors listed opposite—no pipe laid 100 years ago in *city streets* would be in service today. But, in spite of the evolution of traffic from horse-drawn vehicles to heavy trucks and buses—and today's vast complexity of subway and underground utility services—cast iron gas and water mains, laid over a century ago, are serving in the streets of more than 30 cities in the United States and Canada. Such service records prove that cast iron pipe combines all the strength factors of long life with ample margins of safety. No pipe that is provably deficient in any of these strength factors should ever be laid in city streets. Cast Iron Pipe Research Association, Thos. F. Wolfe, Engineer, 122 So. Michigan Ave., Chicago 3.

CAST IRON PIPE SERVES FOR CENTURIES

SEWAGE AND INDUSTRIAL WASTES

The Journal of the Federation of Sewage Works Associations

Volume 22 | AUGUST, 1950 | Number 8

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CHECK THESE FACTS ON DORR CLARIFIER PERFORMANCE!

OPERATING DATA DORR SIFEED CLARIFIERS—RADIAL FLOW—ROUND OR SQUARE

Location	No. Yrs.	Data Period	Ave. Flow MGD	Clarifiers No.	Clarifiers Size	Clarifiers W.D.	Det. Hrs.	O'Flow Gal.	Susp. Solids Raw	Susp. Solids Eff.	Susp. Solids % Rem.	Sludge % Sol.	Sludge % VM	B.O.D. Raw	B.O.D. Eff.	B.O.D. % Rem.
Washington, Blue Plains Pl.	2	1944-45	138.3	12	185' Dia.	14	1.88	1250	163	83	49	6.85	67.5	173	129	30.5
Gary, Ind.	4	1941-44	28.11	4	75' Sq.	10	2.8	900	285	104	61	5.32	63	140	72	47.2
Winnipeg, Man.	2	1943-44	22.8	2	115' Dia.	12	1.98	1100	340	150	55	9.8	70.5	310	231	25.5
Battle Creek, Mich.	5	1938-42	4.92	2	80' Dia.	10	3.88	400	252	85	70	5.5	82.5	264	174	34.1
Buffalo, N. Y.	3	1938-41	135	4	160' "	15	1.8	1060	295	114	48	5.77	58	138	107	22.5
Albuquerque, N. M.	7	1938-48	5	1	80' "	12.2	2.21	905	254	91	61	3.99	61	252	150	44.5
Yakima, Wash.	1	1942	8.5	4	90' "	9	4.32	373	110	23	74	8.96	74.4	175	92	50
Appleton, Wis.	7	1936-45	4.8	2	70' "	10	2.99	623	276	63	77	5.6	58	284	141	50
Baltimore, Md.	4	1939-44	88.5	3	170' "	12	1.64	1380	214	83	61	3.9	62.7	281	204	27.5
Springfield, Ohio	4	1937-40	14.8	2	80' "	10	1.55	1160	166	63	62	—	—	90	43	52
Mansfield, Ohio	2	1944-45	3	1	85' "	12	2.38	965	300	87	56	4.2	76	227	139	38.8
Cedar Rapids, Ia.	9	1936-44	4.21	1	70' "	11.5	1.85	1000	354	132	63	5.5	81.2	363	291	24
Austin, Texas	2	1944-45	5.84	1	75' "	12	1.88	1275	283	85	64	4.8	83	285	152	46.3
Neenah-Menasha, Wis.	4	1942-45	7.83	2	75' "	10	1.8	1700	691	108	72	—	—	—	—	—
Denver, Colo.	5	1938-43	46	4	140' "	9.7	2.34	750	187	44	77	5.8	76	212	109	49
Sheboygan, Wis.	1	1944	6.4	2	80' "	10	2.8	635	342	60	82	7.2	81.1	513	285	44
Ypsilanti, Mich.	3	1943-45	1.66	2	40' "	9	2.5	860	226	87	62	8.2	71.4	141	95	33
Monroe, Mich.	8	1938-46	4.3	2	110' "	7.5	3.56	370	329	75	77	5.23	67.7	135	73	46

A few moments study of these figures will give you a clear idea of what kind of performance you can expect Dorr Clarifiers to deliver.

These are long-term records . . . obtained by competent plant chemists at well established installations. We believe they cannot be bettered.

Performance is one of the primary factors upon which Clarifier excellence should be judged. Are you getting the best?

Close-up of peripheral overflow from one of four 160' dia. Dorr Sifeed Clarifiers at Buffalo, N. Y.

We'd like to give you some figures on Dorr Clarifier repair costs too. Ask a Dorr engineer for the facts.

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RESEARCH ENGINEERING DORR EQUIPMENT

Sewage Works

SLUDGE DEWATERING AND DISPOSAL *

By Samuel I. Zack

Chief Sanitary Engineer, Gannett Fleming Corddry and Carpenter, Inc., Harrisburg, Pa.

Disposal of solids removed as sludge from sewage by primary and secondary sedimentation is the difficult and costly part of sewage treatment. Sludge thus removed varies in quantity depending on the method of treatment, is composed of a large percentage of putrescible organic solids, and is high in moisture content.

Sewage sludge is highly putrescible and, unless properly processed for disposal, is the principal potential nuisance encountered in the treatment of sewage. Unless disposed of, sludge can also be a nuisance from the standpoint of accumulation, even though properly processed. The purpose of processing and disposal, therefore, is to render the sludge unobjectionable and to get rid of it to avoid excessive accumulations.

Sludge Removed from Sedimentation Tanks

Data on the amounts of sludge per capita per day and the percentage of solids and organic content are presented in Table I. The figures vary over a considerable range; in general, however, organic content and per cent solids are higher and sludge produced per capita is lower for primary settled sludge than for activated sludge with primary and secondary settling.

Concentration

After removal from sedimentation or digestion tanks, sludge can be concentrated in separate tanks to reduce the water content, to conserve digester capacity, and to facilitate dewatering on vacuum filters. Concentration of sludge (1) has been accomplished by separate thickening tanks, reductions in volume of sludge of 75 to 88 per cent having been obtained at Baltimore, Md., by their use. Unthickened sludge has a solids content of 0.9 to 1.1 per cent, and thickened sludge has a solids content of 1.4 to 2.1 per cent. Time is an important element in concentrating sludge. Primary settling tank sludges can be thickened to 6 to 8 per cent solids content by holding in settling tank sludge hoppers or in separate concentration tanks. Chemically precipitated sludges can be thickened to about 8 per cent solids content.

Donaldson reports that activated sludge ranging in solids content from 0.4 to 0.5 per cent was concentrated to 1.35 to 3.48 per cent solids by storage. Solids content of 5.94 per cent in digested sludge was increased to 7.94 per cent by storage.

The solids content in sludge is increased from 8.03 per cent to 9.09 per cent by thickening at the Minneapolis-St. Paul (Minn.) Sanitary District (2), with a corresponding reduction of 27 per cent in the volume of sludge going to the vacuum filters.

* Presented at 1949 Annual Meeting, Pennsylvania Sewage and Industrial Wastes Assn.; State College, Pa.; Aug. 24–26, 1949.

TABLE I.—Sludge Removed from Sedimentation Tanks

Location	Year[1]	Sludge Removed		Dry Solids		Org. Matter in Dry Solids (%)
		(g.c.d.)	(lb./cap./day)	(lb./cap./day)	(%)	
(a) Primary Settled						
Grand Rapids, Mich.	1946–47	0.34	2.9	0.12	5.6	70.2
Hartford, Conn.	1948	0.23	2.0	0.13	6.7	71.2
Minneapolis-St. Paul Sanitary District	1947	0.40	3.4	0.27	8.0	68.9
Racine, Wis.	1946	0.25	2.1	0.15	7.2	67.0
Buffalo, N. Y.	1945–46	0.19	1.6	0.12	7.2	68.5
Dist. of Columbia[2]	1947	0.13	1.1	0.09	8.2	64.9
San Francisco, Calif. Richmond Sunset	1944–45	0.23	1.9	0.08	4.3	84.1
Frederick, Md.	1948	0.38	3.2	0.16	5.0	—
(b) Chemical Precipitation						
Wilmington, Ohio[3]	1940	0.41	3.5	0.32	3.7	65.0
Lebanon, Ohio[3]	1940	0.89	7.6	0.89	9.6	26.9
(c) Activated Sludge with Primary and Secondary Settling						
Springfield, Ill.	1942	0.65	5.5	0.22	4.1	57.2
Jackson, Mich.	1947–48	0.54	4.6	0.25	5.3	59.0
Ann Arbor, Mich.	1947	0.83	7.0	0.19	2.8	76.9
Cleveland, Ohio Easterly	1947	0.73	6.2	0.24	3.8	64.0
New Britain, Conn.[4]	1944	0.27	2.3	0.17	7.5	—
Belleville, Ill.[3]	1944–45	0.62	5.3	0.17	3.3	69.0
Marion, Ind.	1948	0.65	5.5	0.29	5.2	61.0

[1] Annual report.
[2] Based on population equivalent.
[3] Report on operating tests, dated June 16, 1941, Ohio Department of Health.
[4] Guggenheim process.

Excess activated sludge was thickened in concentration tanks from a solids content of 2.54 per cent to 4.05 per cent during the last half of 1947 at the Southerly plant in Cleveland, Ohio (3).

Sludge was thickened by storage to reduce the volume for barging to sea at the Elizabeth (N. J.) Joint Meeting plant. In 1944, the raw sludge had a solids content of 5.4 per cent before storage and a solids content of 8.2 per cent after storage. The reduction in volume by concentration amounted to about 45 per cent.

Some success has been reported in thickening sludge by the use of chemicals, both for precipitation and flotation. The flotation method, using alum, has been in use at Plainfield, N. J.

Concentration of sludge reduces the digestion capacity required and makes it possible to operate vacuum filters at higher rates, based on the amount of dry solids that can be dewatered per square foot per hour. It also reduces the volume that has to be barged where sea disposal is employed.

Digestion

The most common method of processing sludge is by digestion of the organic solids and drying the digested sludge on sand beds. Digestion is ac-

complished in Imhoff tanks, or in covered heated or unheated digesters. The collection and use of gas for fuel or power generation is incidental to the digestion of the sludge.

Data on sludge removed from digestion tanks are presented in Table II. Where digestion capacity is adequate, digested sludge has a higher solids content than raw sludge removed from primary sedimentation tanks. It has a much lower volatile content than raw sludge, and this figure varies in accordance with the amount of digestion accomplished. The volume of sludge to be handled is reduced 35 to 50 per cent by digestion.

Drying Beds

Either open or glass covered sand beds are utilized for drying sludge. Open beds have been used generally at the smaller treatment plants, and for the larger plants located on isolated sites of ample area, or in warm, dry climates.

Glass covered beds cost more per square foot, but more sludge can be dried on properly designed covered beds. Consequently, the drying bed area required is from 30 to 50 per cent less than for open beds. In order to hold costs in line with financing, construction of glass enclosures has been deferred on several recent projects

TABLE II.—Sludge Removed from Digestion Tanks

Location	Year[1]	Sludge Removed		Dry Solids		Org. Matter in Dry Solids (%)
		(g.c.d.)	(lb./cap./day)	(lb./cap./day)	(%)	
(a) Primary Settled and Digested						
Grand Rapids, Mich.	1946–47	0.19	1.61	0.078	5.0	60.2
Hartford, Conn.	1948	0.12	1.01	0.050	4.9	50.7
Buffalo, N. Y.	1947–48	0.07	0.60	0.068	11.1	60.0
Dist. of Columbia[2]	1947–48	0.059	0.50	0.040	8.0	45.9
Racine, Wis.	1946	0.045	0.38	0.033	8.7	48.0
San Francisco, Calif.						
Richmond Sunset	1944–45	0.19	1.60	0.028	1.7	68.1
(b) Activated Sludge with Primary and Secondary Settling						
Jackson, Mich.	1947–48	0.31	2.60	0.18	6.9	45.0
Springfield, Ill.	1942	0.075	0.64	0.07	5.9	40.9
Ann Arbor, Mich.	1947	0.39	3.25	0.04	1.3	65.3
Marion, Ind.[3]	1948	0.41	4.20	0.18	4.2	49.7
(c) Trickling Filter with Primary and Secondary Settling						
Elgin, Ill.	1945–46	—	—	—	3.7[4, 5]	64.3[4, 5]
					4.2[4, 6]	60.2[4, 6]
Galesburg, Ill.	1947	—	—	—	7.8[5]	43.1[5]
Worcester, Mass.	1944	0.28[4]	2.34[4]	0.17[4]	7.4[4]	45.9[4]
		0.09[6]	0.80[6]	0.03[6]	3.5[6]	47.3[6]

[1] Annual report.
[2] Based on population equivalent.
[3] Sludge digested with garbage and whey.
[4] Imhoff tank sludge.
[5] Digester sludge.
[6] Secondary settling tank sludge.

TABLE III.—Digested Sludge Removed from Drying Beds

Location	Year[1]	Type of Treatment	Sludge Vol. (cu. ft./cap./yr.)	Solids (%)
Springfield, Ill.	1942	Act. sludge	24.8[2]	50
Jackson, Mich.	1947	Act. sludge	2.80	36
San. Dist. of Chicago	1947	Imhoff tank	—	32
Elgin, Ill.	1945–46	Tr. filt., prim. and sec. settl.	0.67	49.5
Worcester, Mass.	1944	Imhoff, tr. filt., final settl.	2.92	—

[1] Annual report.
[2] Pounds.

until growth in population catches up with design capacity.

Digested sludge from Imhoff tanks at the West Side plant of the Sanitary District of Chicago is dried on open sand beds, then removed from the beds and loaded into cars by means of a mechanical bed cleaner and loader. Sludge removed from the sand beds is suitable for fertilizer, soil building, or land fill.

Some typical data on sludge removed from drying beds are given in Table III. Operating reports by municipalities do not provide much information on sludge removed from drying beds. The data shown indicate that the moisture content is from 50 to 68 per cent in sludge taken off the beds.

Mechanical Dewatering

In the past 15 years there has been a definite trend by the larger municipalities toward mechanical dewatering of sludge on vacuum filters (Figure 1). Various types of bag, plate, and frame filter presses have been operated

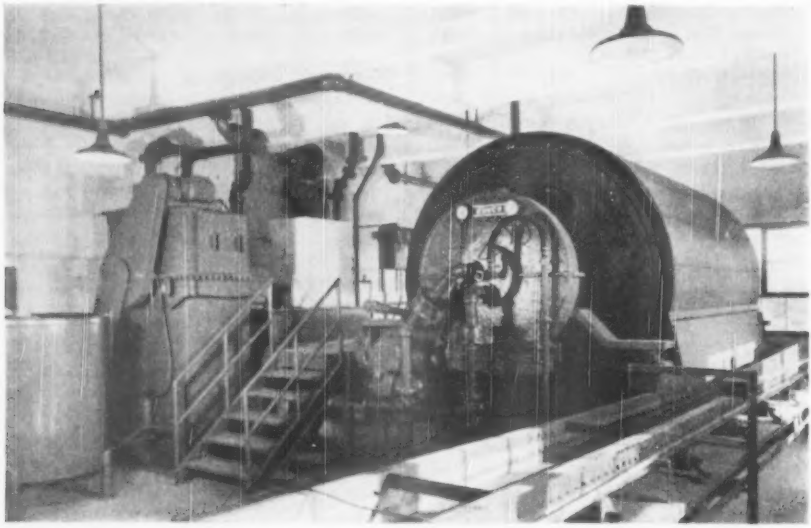

FIGURE 1.—Conditioning equipment and vacuum filter for sludge dewatering at Battle Creek, Mich.

TABLE IV.—Sludge Dewatered on Vacuum Filters

Location	Year[1]	Type of Sludge	Sludge Applied to Filter		Sludge Cake Removed from Filter			Conditioning Chemicals	
			(lb./sq. ft.)	Solids (%)	Wet Cake (lb./sq. ft.)	Solids (%)	Dry Solids (lb./sq. ft./hr.)	CaO (%)	$FeCl_3$ (%)
(a) Primary Settled Sludge									
Minneapolis-St. Paul	1947	Raw	36.1	9.1	10.4	31.5	3.3	3.7	1.3
Washington, D. C.	1947–48	Dig., elutr.	98.0	8.0	28.0	27.7	7.8	—	3.6
Detroit, Mich.	1946–47	Part dig.	69.0	8.6	19.0	31.2	5.9	7.3	2.0
San Diego, Calif.	1947–48	Dig., elutr.	37.5	4.8	6.5	27.7	1.8	—	5.8
Cleveland, Ohio									
Westerly	1947	Imhoff, sep. dig.	43.5	7.8	10.4	32.9	3.4	11.0	2.8
Buffalo, N. Y.	1947	Digested	—	—	—	40.0	—	10.7	3.1
Hartford, Conn.	1948	Dig., elutr.	111.0	5.1	16.9	33.8	5.7	—	2.2
Springfield, Mass.	1947	Dig., elutr.	54.5	11.5	18.0	34.8	6.3	1.4[2]	0.6
San Francisco, Calif.									
Richmond Sunset	1944–45	Dig., elutr.	157.0	3.3	21.5	24.0	5.2	—	5.0
Dearborn, Mich.	Apr. 1948	Part dig., part chem. prec.	—	—	—	37.7	—	9.5	1.6
Auburn, N. Y.	Apr. 1949	Raw	10.9	5.6	20.0	30.0	6.1	20.0[3]	2.7
Wayne County, Mich.									
Wyandotte	1948	Raw set., chem. prec.	6.2	7.6	13.4	35.0	4.7	13.8	4.3
(b) Activated Sludge with Primary and Secondary Settling									
Columbus, Ohio	1948	Digested	—	—	—	25.3	—	16.0	4.1
Cleveland, Ohio[4]	1947	Digested	44.2	7.0	10.7	28.8	3.1	10.5	5.8
San. Dist. of Chicago									
Calumet	1947	Raw	—	2.6	—	17.2	—	—	5.6
Southwest	1947	Raw	—	1.5	—	16.1	—	—	—
New Britain, Conn.[5]	1944	Raw	61.5	7.5	16.5	28.0	4.6	35.0[6]	3.2
	1945–46	Raw	—	—	17.0	36.5	6.2	26.0[6]	2.4
Lansing, Mich.	July 1947	Dig. with garbage	—	—	15.0	31.2	4.7	8.4	4.3

[1] Annual report. [2] Aluminum sulfate. [3] Lime.
[4] Activated sludge from Easterly Imhoff, preaeration, and trickling filter; sludge from Southerly, all digested.
[5] Guggenheim process. [6] Prestoline.

in this country, but have not acquired popularity due to the labor required for operation and for removal of press cake. Centrifuges have not received general acceptance because of the presence of fine solids in supernatant liquor.

Except for the very small plants, the first cost of a vacuum filter installation is less than for drying beds. However, due to operating costs and the cost of chemicals for conditioning sludge, it is not economical to use vacuum filters for contributory populations less than 25,000 to 50,000. However, under some circumstances (such as critical plant site or presence of certain industrial wastes) it is feasible and desirable even for the smaller communities to use vacuum filters instead of drying beds, even though costs may be higher.

Vacuum filters are being used to dewater undigested and digested sludge taken out of sewage in primary treatment by plain sedimentation and chemical precipitation processes, and in secondary treatment by rock filters or activated sludge aeration, in each case followed by final sedimentation.

Normal practice is to utilize lime and ferric chloride for conditioning raw sludge from primary treatment, or undigested sludge from any treatment process preparatory to dewatering by vacuum filters. Ferric chloride alone is a suitable sludge conditioner for raw sludge produced by the activated sludge process, provided the amount of primary settled sludge removed is less than the amount of secondary settled sludge. The quantity of lime and ferric chloride required for conditioning digested sludge is very high. If digested sludge is elutriated or washed with 3 to 5 volumes of water per volume of sludge, it can be conditioned quite economically with ferric chloride alone.

Ferric sulfate and ferrous sulfate have been tried as sludge conditioners, but without a great deal of success. Alum has been used with some measure of success at Springfield, Mass. (4), on digested primary sludge after elutriation when ferric chloride was hard to get.

The filter cake produced from raw or undigested primary, chemically precipitated sludge or digested sludge from secondary treatment has a moisture content ranging from 60 to 75 per cent. A mixture of undigested settled primary and activated sludge

TABLE V.—Vacuum Filter Cake Produced

Location	Year[1]	Type of Sludge	Filter Cake (lb./cap./day)	
			Wet	Dry Solids
Minneapolis-St. Paul Sanitary District	1947	Settled, raw	0.67	0.21
Detroit, Mich.	1946–47	Settled, part dig.	0.38	0.12
Hartford, Conn.	1948	Settled, dig.	0.12	0.04
San Francisco, Calif. Richmond Sunset	1944–45	Settled, dig.	0.12	0.03
Neenah-Menasha, Wis.	1948	Settled	3.35[2]	1.07[2]
Stamford, Conn.	1948	Settled, dig.	0.10	0.03
Springfield, Mass.	1948	Settled, dig.	0.07	0.03
New Britain, Conn.	1945–46	Guggenheim, settled	0.58	0.21
Lansing, Mich.	July 1947	Act. dig. with garbage	0.42	0.13
Cuyahoga Falls, Ohio	1948	Act., settled	0.21	0.06
Tenafly, N. J.	1948	Act., settled	0.65	0.10

[1] Annual report.
[2] 0.38 and 0.12 lb. per cap. per day, based on population equivalent.

TABLE VI.—Suspended Solids in Filtrate from Vacuum Filters

Location	Year[1]	Type of Sludge	Susp. Sol. in Filtrate (p.p.m.)
Minneapolis-St. Paul	1947	Settled	110
Washington, D. C.	1947–48	Settled dig., elutr.	160
Cleveland, Ohio			
Westerly	1947	Imhoff and sep. dig.	353
Southerly	1947	Dig., activated	457

[1] Annual report.

can be dewatered to 75 or 80 per cent moisture, and settled activated sludge to 80 or 85 per cent moisture.

Vacuum filter cake from digested sludge can be used for land fill, soil building, or fertilizer, about the same way as digested sludge from sand drying beds. Whereas sludge from sand beds has to be handled manually or by a rather complicated mechanical sludge bed cleaner and loader, filter cake is dumped onto a belt, which can be made to discharge to a pile, directly into a truck, or through a storage hopper.

Undigested sludge filter cake has been discharged to an isolated dump, especially if heavily dosed with lime. However, such disposal is always a potential nuisance and hazard, aesthetically at least.

Data on sludge dewatered on vacuum filters are presented in Table IV. Table V gives the wet filter cake and dry solids in wet filter cake, expressed as pounds per capita per day, for various vacuum filter installations. It is obvious, from the data presented thus far, that the weight of filter cake to be handled and disposed of is much less than the weight of liquid sludge removed from sedimentation tanks and digestion tanks.

The suspended solids in the filtrate from vacuum filters (Table VI) vary from 110 to about 450 p.p.m. Elutriation data for a few installations are shown in Table VII.

Lagooning

Many municipalities in this country utilize lagoons (5) as an emergency or supplementary means for disposing of sludge when drying beds are inadequate, or when the capacities of existing installation of drying beds or other means of disposal, such as vacuum filters or incinerators, have been exceeded, or during temporary shutdowns of equipment for repairs. Sizeable municipalities are reporting use of lagoons. The Chicago Sanitary District (6) reports that in 1947 over 100,000 tons of undigested, dry solids from Imhoff tanks and activated sludge treatment process were disposed of to lagoons to supplement other means of disposal. The volatile content of this sludge was about 67.5 per cent. Lagoons have been used for disposal of undigested, activated sludge at Houston, Tex., and are still in use for all the sludge produced at Indianapolis, Ind. Rahway, N. J., has disposed of undigested, primary sludge in this manner. A number of cities, including Akron, Ohio; Baltimore, Md.; Battle Creek, Jackson, and Ann Arbor, Mich.; Dallas, Tex.; etc., have utilized lagoons for disposal of digested sludges.

TABLE VII.—Elutriation Data

Location	Ratio of Wash Water to Sludge Volume	Alkalinity (p.p.m.)		Elutriate		
		Digested Sludge	Elutriated Sludge	Susp. Solids (p.p.m.)	Alkalinity (p.p.m.)	5-Day B.O.D. (p.p.m.)
Washington, D. C.	1.5	3,100	790	2,950	1,600	680
San Diego, Calif.	—	4,000	1,168	—	—	—
Hartford, Conn.	3.0	2,982	224	—	804	—

At Dallas, lagoons holding Imhoff sludge are discharged to the river twice a year during high water. At Dayton, Ohio, 31 per cent of the sludge was discharged to lagoons during 1946. At Toledo, Ohio, over 30,000 cu. yd. of sludge were discharged in 1947 to a marsh, whereas only about 11,500 cu. yd. were put onto the drying beds.

Indianapolis (7) has 13 lagoons covering an area of 55 acres, which amounts to about 6 sq. ft. of lagoon surface per capita; 12 of the lagoons remain in operation while one is being cleaned. The municipality furnishes a power shovel to load farmers' trucks; farmers get this sludge free of charge. Most of the hauling is done in winter when the ground is frozen. Primary settled and activated sludges are discharged to the lagoons, with solids content of 7.5 and 1.1 per cent, respectively. Sludge removed from lagoons has a solids content of 25 per cent and a nitrogen content of 2.5 per cent. The lagoon volume provided in various places varies anywhere from 0.4 to 6 cu. ft. per capita. Digested sludge at Baltimore compacted in the lagoons to 70 per cent moisture content.

Use of lagoons for either digested or undigested sludges, in most cases, has resulted in complaints due to odors. Therefore, lagoons cannot be considered as a suitable permanent means of disposal, except in very isolated locations.

Heat Drying and Incineration

Many municipalities have adopted either heat drying of sludge to produce fertilizer or complete incineration as the means of final disposal of the sludge. Filter cake having a moisture content of 60 to 70 per cent can be burned without, or with very little, auxiliary fuel once combustion is started; the B.t.u. value of raw sludge, of course, is greater than for digested sludge. Heat drying of sludge requires auxiliary fuel, which can be supplied by the digester gas, or by oil or coal.

Burning of sludge requires a temperature of 1,000° to 1,200° F. Deodorizing temperatures of at least 1,100° F. are required for odor control in critical locations. Drying takes place at a temperature of 700° F., which is considered high enough to kill bacteria, even in undigested sludge.

Dryer-incinerators have been generally used where it was found desirable only to dry sludge, or to burn it or dry it at will. Multiple-hearth incinerators are to be installed at Toronto, Ont., suitable for either burning or drying of sludge filter cake. Milwaukee, Wis., dries sludge with rotary dryers. Although early experience in drying sludge was with rotary dryers, very few have been installed for that purpose in recent years.

A spray dryer has been in operation at Plainfield, N. J. (8), for a number of years; experimentation with the method of distributing the sludge through the drying tower is still going on. The spray dryer has been used on liquid sludge and on filter cake.

Stamford, Conn. (9), utilizes stack gases from the refuse incinerator to pre-dry the sludge filter cake from primary digested sludge. The sludge is pre-dried to a moisture content of about 6 to 10 per cent, in which condition it can be sold as fertilizer or burned in the refuse incinerator.

It appears that sludge produced by chemical precipitation, or by complete treatment, has too high a water content for direct burning with refuse without first pre-drying.

Several manufacturers have advocated a mechanically stoked refuse incinerator constructed with an auxiliary sludge drying hearth. Such a unit has been in operation at the Lederle Laboratories in Pearl River, N. J., for burning rubbish, sewage sludge, and spent media from laboratory processes. With adequate control of hot and cold gases, the two-hearth unit should be

suited for burning a combination of sludge and garbage, but it has not been demonstrated whether dry sludge can be taken off for disposal other than burning.

Gas from digesters can be best utilized as auxiliary fuel for drying digested sludge, whereas if the sludge is incinerated, the digester gas can be utilized for power production or for other uses in the plant. At present there is a demand for organic fertilizers; dried sewage sludge can be sold at a good price, thus making it worthwhile to utilize the gas for drying sludge to make fertilizer.

Heat dried, undigested sludge has a higher fertilizer value and is, therefore, more valuable for this purpose than digested sludge. Due to the fact that the capital investment is high for providing digestion space for activated sludge, which has a high nitrogen content when undigested, economics at the present time favor heat drying in undigested form to produce fertilizer.

The price of heat dried activated sludge has been as high as $28.00 per ton, is currently around $18.00 to $20.00 per ton, and is not expected to go much lower than $12.00 per ton. At prices below $12.00 per ton, it would be more economical to burn the sludge than to dry it for fertilizer.

Houston, Tex. (10), and Los Angeles, Calif., are typical examples of the larger cities that have recently adopted heat drying of activated sludge to produce fertilizer. The plans for the proposed treatment plants at Harrisburg, Scranton, Bradford, and Bloomsburg, Pa., provide for either drying the sludge to produce fertilizer, or completely burning it.

The sludge produced at Harrisburg will be primary settled and digested, but flexibility will make it possible to dry or to incinerate undigested sludge. The sludge produced at Bloomsburg will be from chemical precipitation of sewage, which includes a large amount of industrial wastes. This undigested sludge will be dewatered on vacuum filters and burned with refuse consisting of rubbish and garbage. Undigested sludge from partial activated sludge treatment will be burned with refuse in the proposed Bradford plant. The incinerator-dryer at Scranton will operate on undigested, activated sludge, using coal as auxiliary fuel.

Pertinent data on heat drying of sludge are shown in Table VIIIa. The Sanitary District of Chicago heat dries undigested activated sludge at the Calumet and Southwest plants to produce fertilizer. The moisture content of the filter cake at Calumet averages 82 per cent; at the Southwest plant, 83.9 per cent. The sludge is dried to a moisture content of about 5 to 6 per cent. Primary settled and digested sludge is heat dried at Battle Creek, Mich.; Sheboygan, Wis.; and Stamford, Conn. The filter cake ranges from 65 to 80 per cent in moisture content, and the sludge produced ranges from 6 to 11 per cent in moisture content. Undigested, settled, activated sludge is heat dried at Tenafly, N. J. (Figure 2), and either sold as fertilizer or incinerated with refuse. The filter cake has a moisture content of 85 per cent, and the heat dried sludge a moisture content of 15 per cent. In the plants referred to above, flash dryers are utilized for drying the sludge and the sludge furnaces for incineration, except at Tenafly and Stamford, where incineration takes place in a refuse incinerator (Figure 2).

Activated sludge is digested with ground garbage at Lansing, Mich. (11). The digested sludge is dewatered on vacuum filters and burned in a multiple-hearth incinerator. An endeavor also has been made to dry the sludge in this type of incinerator; the data shown for July, 1947, are typical for this operation. Sludge can be dried to a moisture content of about 25 per cent. Efforts to dry the sludge

TABLE VIII.—Heat Drying of Sludge and Disposal by Incineration

No.	Plant: Location	Year	Population[1]: Tributary	Population[1]: Equivalent Load	Type of Sludge	Filter Cake: Moisture (%)	Filter Cake: Vol. Sol. (%)	Filter Cake: To Dryer (tons/hr.)	Filter Cake: Burned (tons/day)	Dryer: Make	Dryer: Oper. (hr./yr.)	Dryer: H_2O Evap. (tons/ton dry sol.)
	(*a*) Heat Drying											
1	San. Dist. of Chicago, Ill. Calumet	1947	—	415,000[2]	Act. settled	82.8	—	100[3]	—	Raymond system	—	4.9
2	Southwest	1947	—	2,900,000[2]	Act. settled	83.9	—	475[3]	—	Raymond system	—	4.6
3	Battle Creek, Mich.	1948[4]	43,300	53,800	Prim. settled, dig.	78.5	—	1.9	—	Raymond system	578	3.5
4	Duluth, Minn.	1948	80,000	124,300	Prim. settled, dig.	74.6	—	1.6	—	Raymond system	527	2.9
5	Tenafly, N. J.	1948[5]	9,500	9,500	Act. settled	85	—	0.63	—	Raymond	1,460	5.4
6	Sheboygan, Wis.	1948[4]	45,200	68,400	Prim. settled, dig.	65.4	—	1.26[3]	—	Raymond system	1,826	1.8
7	Stamford, Conn.	1948[4]	45,000	67,500	Prim. settled, dig.	67	—	1.5	—	Raymond	560	2.0
8	San Diego, Calif.	1948	300,000	—	Prim. settled, dig.	72.3	—	—	—	Raymond system	—	2.5
9	Lansing, Mich.	1947[9]	82,000	—	Act., dig. with garbage	68.8	—	1.7	—	Morse Boulger	10.1[10]	1.85
	(*b*) Disposal by Incineration											
10	Minneapolis-St. Paul, Minn.	1947	900,000	1,230,000	Prim. settled	68.5	64.0	—	335	—	—	—
	Cleveland, Ohio											
11	Westerly	1947	—	—	Prim. settled, dig.	66.8	44.4	—	19	—	—	—
12	Southerly	1947	—	—	Act., dig.	71.1	45.0	—	142	—	—	—
13	Columbus, Ohio	1948[12]	—	—	Act., dig.	74.7	40.0	—	32	—	—	—
14	Detroit, Mich.	1946–47[13]	2,400,000	—	Prim. settled, partially dig.	68.8	56.0	—	360	—	—	—
15	Wayne County, Mich.[14]	1948[15, 16]	—	—	Part settled, part chem. prec.	66	45	—	45[17]	—	—	—
16	Buffalo, N. Y.	1947–48	620,000	920,000	Settled, dig.	60	56.1	—	56	—	—	—
17	Cuyahoga Falls, Ohio	1948[4]	30,000	—	Act. settled	70	52.4	—	0.75[18]	—	—	—
18	Neenah-Menasha, Wis.	1948	24,000	216,000	Prim. settled	68	44	—	2.0[19]	—	—	—
19	Springfield, Mass.	1948	140,000	160,000	Prim. settled, dig.	62.2	43.4	—	1.4[19]	—	—	—
20	New Haven, Conn.	1948[21]	—	—	Prim. settled, dig.	72.7	52.7	—	1.13[19]	—	—	—
21	Duluth, Minn.	1948	80,000	124,300	Prim. settled, dig.	74.6	47.0	—	1.61	—	—	—
22	Piqua, Ohio	1948[23]	—	—	Prim. settled[24]	85.8	74.7	—	0.85[19]	—	—	—

TABLE VIII.—(Continued)

Plant No.	Incinerator			Auxiliary Fuel								Moisture in Dried Sludge (%)
				Per Ton Dry Solids			Per Ton Water		Per Ton Filter Cake			
	Make	Oper. (hr./yr.)	H_2O Evap. (tons/ton comb.)	Oil (gal.)	Gas (cu. ft.)	Power[1] (kw.-hr.)	Oil (gal.)	Gas (cu. ft.)	Oil (gal.)	Gas (cu. ft.)	Power[1] (kw.-hr.)	
						(*a*) Heat Drying						
1	—	—	—	—	—	—	26	—	21	—	—	5.9
2	—	—	—	—	—	—	—	—	—	—	—	4.5
3	—	—	—	—	—	58	—	4,700	—	3,620	13	11
4	—	—	—	—	—	—	—	5,420[5]	—	4,000	12	3
5	Pittsburgh-Des Moines[6]	—	—	—	—	142	6.7	—[7]	5.6	—[7]	22	15
6	—	—	—	—	—	—	—	—	—	—	—	9.8
7	Pittsburgh-Des Moines[6]	—	—	—	—	75	—	—[7]	—	—[7]	40	6
8	—	—	—	—	—	74	—	6,670[8]	—	4,630	22	10
9	—	—	—	—	—	—	Negl.	As needed	Negl.	As needed	—	26.1[11]
						(*b*) Disposal by Incineration						
10	Nichols Herreshoff	—	3.7	0.60	—	9.6	—	—	0.19	—	3.0	—
11	Nichols Herreshoff	—	4.5	0.72[12]	4,300[12]	—	—	—	0.24[12]	1,420[12]	—	—
12	Nichols Herreshoff	—	5.6	—	1,280	—	—	—	—	370	—	—
13	Nichols Herreshoff	—	7.5	23.3	—	—	—	—	5.9	—	—	—
14	Nichols Herreshoff	—	3.8	0.55	—	—	—	—	0.18	—	—	—
15	Nichols Herreshoff	—	4.3	3.4	—	—	—	—	1.2	—	—	—
16	Raymond system[18]	8,278	2.7	0.22	3,800	—	—	—	0.09	1,510	—	—
17	Raymond system[20]	1,548	4.4	25.5	—	—	—	—	7.7	—	—	—
18	Raymond system[18]	7,208	4.9	35.9	—	—	—	—	11.5	—	—	—
19	Raymond system	1,240	3.3	—	2,000	65	—	—	—	800	27	—
20	Nichols Herreshoff	12[10]	4.9	33.2	2,700	—	—	—	9.4	760	—	—
21	Raymond system[18]	690[22]	6.3	—	2,730	48	—	—	—	700	12	—
22	Nichols Herreshoff	21[10]	8.2	88	—	—	—	—	12.2[25]	—	—	—

[1] Estimated. [2] From 1948 report on engineering work; part of sludge dried. [3] Tons per day. [4] Data from plant superintendent, by letter. [5] Deodorizing. [6] Garbage incinerator. [7] Incinerator gas. [8] Calculated. [9] Month of July. [10] Hours per day. [11] Ignites if dried to 10 per cent moisture. [12] 38 per cent oil and 67 per cent gas used during standby periods. [13] 10 months. [14] Data from monthly reports. [15] Wyandotte plant. [16] Month of September. [17] Based on days operated. [18] Deodorizing with preheater. [19] Tons per hour. [20] Deodorizing without preheater. [21] Month of January. [22] 7 months per year. [23] Sept. 7 to Dec. 31. [24] Liquid sludge not dewatered on vacuum filters. [25] Per ton liquid sludge.

to a 10 per cent water content have resulted in ignition and burning of the sludge. As no charge is made for dried sludge, the moisture content of the final product is of no particular concern in this case.

At Grand Rapids, Mich., sludge taken off the drying beds is passed through a grinder and a rotating drum dryer and is placed in 100-lb. bags for sale as "Rapid Gro" fertilizer.

Data pertaining to sludge disposal by incineration are presented in Table VIIIb. Most of the incinerators are utilized for burning either primary settled sludge, or digested sludge from either primary sedimentation or activated sludge. Dearborn and Wayne County, Mich., Wyandotte plant burn part settled and part chemically precipitated sludge, both undigested. The Cuyahoga Falls, Ohio, plant burns activated sludge. All of these sludges, of course, are dewatered on vacuum filters before burning (Figure 3).

In the multiple-hearth furnaces, the wet filter cake is introduced at the top hearth and, by means of rabble arms, is moved to each successive next lower hearth. Combustion takes place in the third or fourth hearth from the top; ash is removed from the lowest hearth. The multiple-hearth incinerator has apparently been more widely used for complete burning of sludge than the flash dryer type.

In the flash dryer type, sludge is first pre-dried with the hot gases returned from the combustion chamber, and then the pre-dried sludge is burned in the combustion chamber of the incinerator. A portion of the dried material has to be returned to the filter cake so that the wet filter cake can be properly handled in the flash dryer.

The larger installations operate the incinerators on a 24-hr. basis, or else keep the furnace hot with standby fuel. The smaller installations are

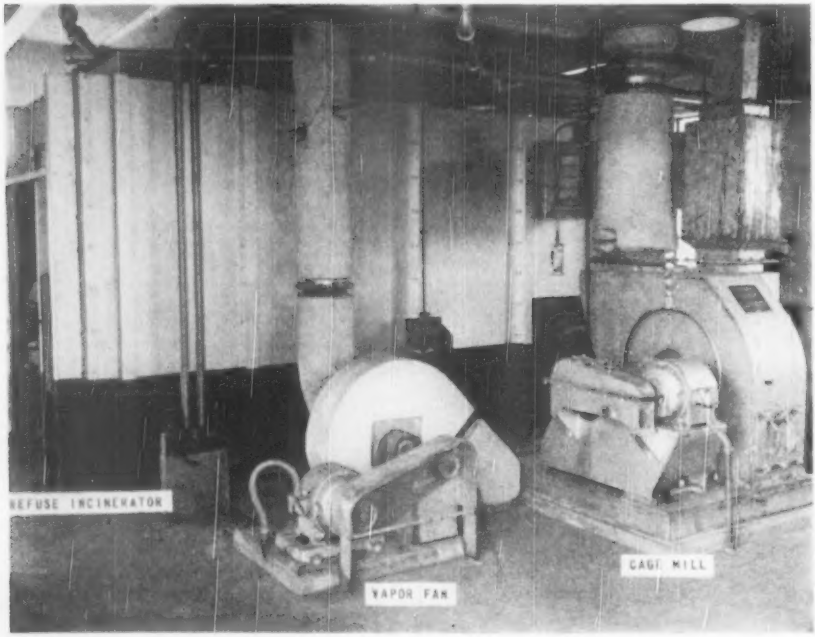

FIGURE 2.—Flash drying equipment and refuse incinerator at Tenafly, N. J.

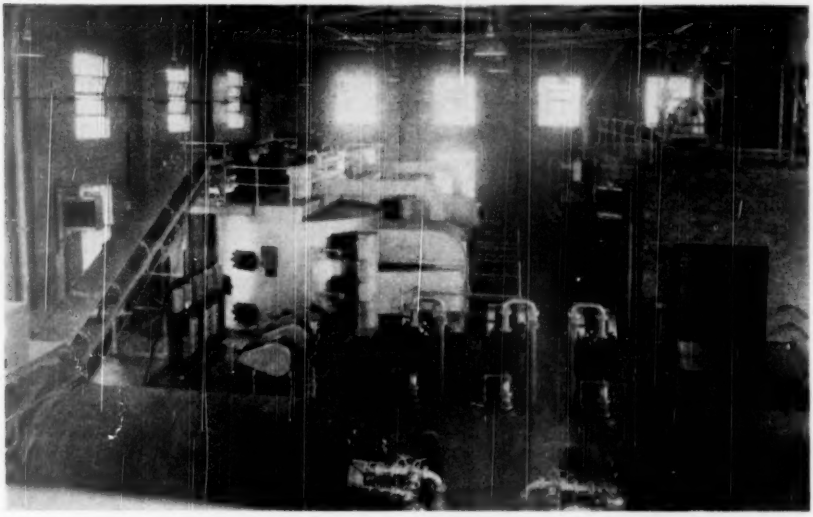

FIGURE 3.—Vacuum filter and multiple-hearth incinerator equipment at Westerly plant, Cleveland, Ohio.

operated intermittently, as needed, during 6 to 8 hr. per day and, in some cases, are allowed to cool down between burning operations.

The amount of auxiliary fuel used varies with the character of the sludge, the mode of operation, and the type of incinerator.

A multiple-hearth furnace was operated at Piqua, Ohio (12), in an endeavor to burn liquid sludge without first dewatering it on a vacuum filter. Data for this type of operation are presented in Table VIIIb. The tons of water evaporated per ton of combustible solids amounted to 8.2. This was much higher than usually results in the burning of vacuum filter sludge cake. The amount of auxiliary fuel required was excessive, 88 gal. being required per ton of dry solids, and 12.2 gal. per ton of liquid sludge. Under normal conditions sludge probably can be more economically disposed of by dewatering on vacuum filters and burning the sludge filter cake, especially where it is not possible to concentrate the sludge to the extent accomplished at Piqua.

Drying and Incineration Temperatures

Temperatures in the various hearths of a multiple-hearth furnace, as reported for the Cleveland Westerly plant in the incineration of sludge cake, and at Piqua, Ohio, in burning liquid sludge, are shown in Table IX. Operating temperatures prevailing in Raymond system dryers and incinerators for various installations are shown in Table X.

TABLE IX.—Incineration Temperatures, in Degrees F.

	Cleveland, Ohio Westerly[1]	Piqua, Ohio[2]	
		Starting	Norm. Oper.
Material burned	Sl. cake	Liquid sl.	Liquid sl.
Hearth No. 1	870	730	750 to 1,030
Hearth No. 2	1,120	950	970 to 1,200
Hearth No. 3	1,270	1,180	1,150 to 1,350
Hearth No. 4	1,210	1,400	1,500 to 1,680
Hearth No. 6	510	990	950 to 1,300
Preheater inlet	320	—	—
Preheater outlet	680	—	—
Cooling air, top of shaft	410	300	440 to 520

[1] 1947 annual report.
[2] 1948 data by letter.

TABLE X.—Operating Temperatures and Deodorizing Equipment, Raymond System Dryer Incinerators [1]

	Cuyahoga Falls, Ohio	San Diego, Calif.	Neenah-Menasha, Wis.	Tenafly, N. J.	Sheboygan, Wis.	Stamford, Conn.	Springfield, Mass.	Duluth, Minn.
Temperature, av. (°F.)								
Cage mill inlet	1,200	1,000	1,200	1,800	720	950–1,100	1,200	1,000
Cyclone discharge	350	250	275	275	275	225–275	230	250
Combustion air	—	400	200	—	180	—	150	340
Stack	550	400	500	—	460	—	400	430
Deodorizing equipment								
Installed	Yes	Yes	Yes	Gases to	Yes[2]	Gases to	No	Yes
Temperature (°F.)	1,000	1,050	1,100	garbage	1,100	garbage	—	—
Fuel used, oil (gal.)	—	—	—	incin.	8	incin.	—	—
Preheater used	No	Yes	Yes	—	Yes	—	—	Yes
Operation (% of des. cap.)	106	125	100	165	65	60	104	107

[1] Data by letter.
[2] Used 20 per cent of time.

Information pertaining to the use of deodorizing equipment is also shown in Table X, as well as the per cent of design capacity at which the various incinerator-dryer installations are operated. It is reported that the high temperatures maintained during operation at Piqua are for eliminating odors in the burning of liquid sludge. Auxiliary fuel required and temperatures in drying and incineration units are affected by the extent of deodorization, and whether deodorization is accomplished with or without a preheater.

B.t.u. and Volatile Content

The B.t.u. value and volatile content of sludge at several installations are shown in Table XI.

TABLE XI.—Heat Value and Volatile Content of Sludge

Plant	Year	Heat Value (B.t.u./lb.)		Vol. (%)
		Dry Sol.	Vol.	
Chicago, Ill. (Calumet)	1947	6,500	10,800	60.1
Cleveland, Ohio	1947	5,350	11,900	45.0
Buffalo, N. Y.	1947–48	5,282	—	56.1
Springfield, Mass.	1948	4,000	—	43.4

Incinerator Ash Disposal

Ash is disposed of as fill in most cases. At Cuyahoga Falls, Ohio; Duluth, Minn.; and Springfield, Mass., it is pumped hydraulically to fill. At Neenah-Menasha, Wis., it is trucked dry to fill. The ash at Minneapolis and Detroit amounts to 0.07 lb. per capita per day; at Buffalo, 0.053 lb. per capita per day. Duluth reports the weight of ash as 45 lb. per cu. ft.

Disposal of Filter Cake

Digested sludge, dewatered on vacuum filters, can be disposed of without nuisance for fill in the same manner as digested sludge taken off the drying beds, or may be used for fertilizer. Washington, D. C. (13), in 1947, shipped to the Department of Correction at Lorton, Va., in freight cars, about 22,000 tons of digested sludge filter cake having a solids content of about 28 per cent. This was 92.4 per cent of the total sludge filter cake production of the plant. The sludge was applied to the soil or stored for future use. It is reported, however, that this sludge has not replaced the use of fertilizer. The remainder of the sludge was hauled by farmers in trucks for use as soil dressing.

Hartford, Conn. (14), disposes of its digested sludge filter cake in a dump, which has caused no particular trouble. Sludge is carried to the dump in cars operating on a narrow gage railroad. The amount of filter cake produced at Hartford is about 0.5 cu. ft. per capita per day.

About 8 tons of raw sludge filter cake has been disposed of as fertilizer at the Minneapolis-St. Paul Sanitary District. This amounts to somewhat less than 2.5 per cent of the plant's filter cake production.

Undigested sludge filter cake removed from the chemical precipitation and settling of sludge at Perth Amboy, N. J., has been disposed of in a dump. Similar sludge disposed of at Dearborn, Mich., before the incinerator was installed gave trouble due to odors when storm drainage leached out the lime.

Disposal by Digestion with Garbage

Ground garbage is added to the digesters at Lansing, Mich., and Marion, Ind. (18). In both places, sewage treatment consists of primary settling, activated sludge, and final settling. Cheese whey is also added directly to the digester at Marion.

Data pertaining to the addition of garbage to the digester are shown in Table XII. Normally, about 5 cu. ft. per capita of digestion space is required for complete treatment by the activated sludge process. When the garbage is added to the digester the space requirement for digestion is indicated to be from 9 to 10 cu. ft. per capita for complete digestion.

A number of municipalities add ground garbage to raw sewage. Except for increasing the solids to be handled, no basic processes for sludge disposal are affected (16).

TABLE XII.—Disposal of Sludge by Digestion with Garbage

Item	Lansing, Mich.	Marion, Ind.[1]
Year	1946	1948
Garbage, wet (lb./cap./day)	0.75	0.230
Dry solids in wet garbage (lb./cap./day)	0.15	0.035
Dry org. sol. in wet garbage (lb./cap./day)	0.135	0.033
Dry org. sol. in sewage (lb./cap./day)	0.27	0.16
Solids in green garbage (%)	20	18
Volatile in garbage (%)	90	91

[1] Whey also added with garbage; average dry solids content 0.0084 and volatile dry solids 0.0075 lb. per capita per day.

Disposal of Liquid Sludge

Liquid digested sludge is disposed of at Marion, Ind., by conveying it with tank trucks and spreading it on land (17). In 1948, over 5 m.g. of sludge having a solids content of 4.2 per cent and volatile content of 49.7 per cent was disposed of in this manner. About 75 per cent of the sludge was handled in a 1,500-gal. tank truck; the remainder, in a smaller truck. The average haul is calculated to be about 40 mi. Based on figures given for the cost of hauling with the 1,500-gal. truck, it appears that the cost of disposal amounts to $7.20 per 1,000 gal., or about $4.55 per ton of dry solids. The revenue derived from the sale of liquid sludge amounted to about $1,400.

New York City operates and maintains boats to haul liquid digested sludge to sea as a means of disposal. This method also is utilized by other coastal cities and, in some cases, undigested sludge is taken out to sea for disposal. At Elizabeth, N. J., undigested, primary settled sludge is concentrated by storage before such sea disposal (18).

Incineration of Filter Cake with Garbage and Rubbish

Primary settled sludge, undigested, is dewatered on vacuum filters and burned in an incinerator with garbage and rubbish at Frederick, Md. (22). The filter cake has a moisture content of about 70 per cent; the ratio of wet garbage and rubbish to wet filter cake

is 2.9 to 1. In order to burn the sludge with refuse successfully, it has to be proportioned manually so that the proper ratios of refuse and sludge filter cake are maintained for satisfactory incineration. The ratio of wet garbage and rubbish to dry solids and wet filter cake is about 10 to 1. The ash produced from the burning of sludge and garbage amounts to 0.13 lb. per capita per day. Data pertaining to the burning of sludge filter cake with garbage and rubbish (Table XIII) show the results obtained in Frederick, and for two proposed in installations where the sludge is to be pre-dried.

Disposal of sludge by burning or drying in combination with the incineration of refuse consisting of rubbish and garbage is a method being adopted quite generally. The burning of refuse provides enough heat for incineration of filter cake from primary undigested sludge without the use of appreciable amounts of fuel. Due to the high ratio of water in filter cake from undigested, chemically precipitated sludge or activated sludge to refuse, it is necessary to pre-dry such sludge before burning with refuse.

Digested sludges having a high ratio of water to be evaporated to their volatile contents probably also would have to be pre-dried before they could be burned with refuse.

Analyses of Sludge

Moisture, volatile, and other ingredients of various sludges, as well as fertilizing values for various installations, are shown in Table XIV. Data on sludge from sand beds, vacuum filters, heat dried, are presented. It is of interest to note that in the filter cake dumped at Hartford, Conn., over a period of years the volatile solids content, ranging from 48 to 70 per cent, was reduced to about 36 per cent. The moisture content was reduced from 66.2 per cent to 42 per cent. The

TABLE XIII.—Incineration of Filter Cake with Garbage and Rubbish

	Frederick, Md.	Bradford, Pa.[1]	Bloomsburg, Pa.[1]	
			Canneries Operating[2]	Canneries Not Operating[3]
Year	1948	—	—	—
Type of sludge	Prim. settled	Activated	Chem. prec.	Chem. prec.
Pre-drying	No	Yes	Yes	Yes
Garbage and rubbish, wet (tons/yr.)	4,914	11,100	850	4,150
(lb./cap./day)	1.5	2.53	2.11	2.11
Sludge, wet (tons/yr.)	1,698	5,600	475	1,825
(lb./cap./day)	0.52	1.28	1.18	0.93
Dry solids (tons/yr.)	501	1,020	141	550
(lb./cap./day)	0.16	0.23	0.35	0.28
Water evap. (tons/yr.)	1,190	4,580	332	1,275
(lb./cap./day)	0.36	1.05	0.83	0.65
Water in filter cake (%)	70	82	70	70
Vol. in dry solids (%)	—	67	67	67
Ratio (weight), wet rubbish and garbage to:				
Wet filter cake	2.9	2.0	1.8	2.3
Water in filter cake	4.1	2.4	2.6	3.2
Dry sol. in filter cake	9.8	10	6.0	7.6
Water evap. from sludge (tons/ton comb.)	—	6.7	3.5	5.0
Ash produced (tons/yr.)	428	—	—	—
(lb./cap./day)	0.13	—	—	—

[1] Design basis of proposed installations.
[2] 2 months.
[3] 10 months.

TABLE XIV.—Analyses of Dewatered Sludges

Location	Year[1]	Type of Sludge	Moisture (%)	Vol. (%)	Humus (%)	K_2O (%)	P_2O_5 (%)	N (%)	NH_3 (%)	Fats
Racine, Wis.	1946	Set., dig., sand beds	43.0	—	47.0	0.5	2.3	—	2.9	—
San. Dist. of Chicago, Ill.										
West Side	1947	Imhoff, sand beds	68.0	48.8	—	—	—	2.15	—	—
Southwest	1947	Raw set. Vac. filt., heat dried	95.5	63.2	—	—	2.4	—	6.4	—
Calumet	1947	Act. Vac. filt., heat dried	94.1	60.1	—	—	2.8	4.9	5.6	6.8
Cleveland, Ohio, Southerly	1947	Act. set., dig. Drying bed	—	47.7	—	—	1.7	3.8	—	14.8
		Act. set., dig. Vac. filt.	—	43.8	—	—	1.5	3.2	—	12.2
Hartford, Conn.	1938–43	Prim. set., dig. Vac. filt.	66.2	47.7 to 70.0	30.0 to 53.0	0.2 to 0.5	1.2 to 2.4	1.7 to 2.3	2.0 to 2.8	—
		Prim. set., dig. Dump	42.0	36.0	35.0	0.10	1.8	1.9	2.3	—
Grand Rapids, Mich.	—	Prim. set., dig., sand beds, heat dried	9.1	40.3	6.5	—	2.50	—	2.5	—
San Diego, Calif.	—	Prim. set., dig., vac. filt., heat dried	10.0	60.0	—	0.13	2.50	3.0	—	—
Tenafly, N. J.	1937–41	Raw act. set., vac. filt., heat dried	15.0	72.4	—	0.5	3.6	—	7.0	—
Sheboygan, Wis.	1948	Prim. set., dig., vac. filt., heat dried	9.8	44.0	—	0.13	1.5	2.2	—	—
Stamford, Conn.	1948	Prim. set., dig., vac. filt., heat dried	6.0	44.0	—	Trace	1.0	3.0	—	—
Springfield, Mass.	1948	Prim. set., dig., vac. filt., heat dried	—	43.4	30.0	0.50	2.40	2.0	—	—
Wilmington, Ohio	1940[2]	Chem. prec., sand beds	—	—	—	0.28	3.75	—	2.01	—
Lebanon, Ohio	1940[2]	Chem. prec., sand beds	—	—	—	0.31	1.31	—	0.8	—

[1] Operation report.
[2] Report of test period.

TABLE XV.—Analyses of Sludges

Location	Lime, as CaO (%)	Sulfates (%)	Fe_2O_3, Al_2O_3 (%)	SiO_2 (%)
Cleveland, Ohio, Southerly				
Drying beds	2.3	2.6	11.4	35.2
Vacuum filters	15.1	2.8	15.7	22.2
Grand Rapids, Mich.	9.5[1]	—	—	—
Hartford, Conn.	—	—	—	0.4 to 1.2[2]

[1] Lime.
[2] As Fe.

other constituents remained practically the same, but the potash content was less in the material from the dump. Further analyses of some of the installations are shown in Table XV.

Sludge Sold or Prepared for Fertilizer

Data pertaining to sludge sold or prepared for fertilizer in various municipalities are shown in Table XVI. Information is also included on the price per ton received for sludge sold as fertilizer and total revenue where information is available.

Dayton, Ohio, reports gross revenue of $10,441.91, with a profit of $6,410.59, from the sale of sludge for fertilizer in 1946; San Diego derived a revenue of $18,117.60 for the 1947–48 year. Grand Rapids (20) disintegrates the sludge dried on sand beds, and after final heat drying sells it for fertilizer. A total revenue of $7,737 was derived from the sale of sludge in 1947.

Conclusions

Sufficient experience is available to indicate that nearly all types of sludges can be dewatered, dried, or incinerated mechanically. Sanitarians no doubt will agree that complete incineration, resulting in an inert ash, affords the most satisfactory solution of a very difficult problem. However, because of the present great demand for organic fertilizers and organic hu-

TABLE XVI.—Sludge Sold or Prepared for Fertilizer

Location	Year[1]	Sludge						
		Type	Sold or Prepared (tons/yr.)	Moisture (%)	How Dried	Unit Weight (lb./cu. ft.)	Price ($/ton)	Total Revenue ($)
Battle Creek, Mich.	1948	Set., dig.	250	11	Flash dryer	36.4	14 to 20	—
Sheboygan, Wis.	1948	Set., dig.	724	9.5	Flash dryer	46.0	5.50	—
Stamford, Conn.	1948	Set., dig.	250	6	Flash dryer	30.0	5.35	—
San Diego, Calif.	1948	Set., dig.	905	10	Flash dryer	—	20	—
Duluth, Minn.	1948	Set., dig.	212	3	Flash dryer	—	12	—
Toledo, Ohio	1947	Set., dig.	950	—	Drying beds	—	—	9,525[2]
Washington, D. C.	—	Set., dig., vac. filt.	21,700	72.3	Vac. filter	—	None	None
Chicago, Ill. (Calumet)	1947	Set., act.	6,900	5.9	Flash dryer	—	—	—
Chicago, Ill. (Southwest)	1947	Set., act.	23,400	4.5	Flash dryer	—	—	—
Tenafly, N. J.	1948	Set., act.	163	15	Flash dryer	—	30 to 40	—
Marion, Ind.	1948	Act., dig.[3]	5,246[4]	95.8	Liquid	—	—	1,385[5]

[1] Annual report.
[2] Fertilizer processing cost $2.99 to $4.31 per ton.
[3] Ground garbage digested with sludge.
[4] Thousands of gallons.
[5] Digested liquid sludge trucked for disposal on farm land; some sold.

mus, it seems wrong to destroy such organic material. The combination permitting drying or incineration offers the answer which meets many situations. Organic matter is conserved by drying only when the demand exists; the sludge can be incinerated when there is no demand for sewage sludge fertilizer, or when economies are adverse to its conservation.

Dewatering of undigested sludge, although it can be done, only solves the problem partially. The water is removed, but putrescible organic matter still remains. Dewatering of digested sludge on vacuum filters provides as good a solution as drying on beds, and sludge can be disposed of in the same manner as bed dried sludge. The vacuum filter method minimizes the manual problem in handling and taking sludge off the beds, which is quite material for large cities.

Lagooning of sludge is a temporary expedient. It is believed that most engineers will agree that, except in unusual situations, it cannot be considered as a permanent means of sludge disposal. At best, it can serve only until other means are provided.

Disposal of sludge at sea has thus far been acceptable, even for as large a city as New York. Restrictions may be placed on this type of disposal in the future, requiring barging of sludge to greater distances. When the distance which sludge must be hauled becomes sufficiently great, economies will lead to mechanical dewatering and incineration of sludge, at least for the larger cities.

From a functional standpoint, there is no reason why mechanical dewatering, drying, and incineration of sludge should not suit every municipality. Economically, this method is limited to larger cities, and drying of sludge on beds will be the best answer for the smaller municipalities for many years to come unless, in exceptional cases, use of digestion and drying beds is limited by restrictions of available plant site. Therefore, the smaller municipalities can be best served by disposing of sludge by digestion and drying beds, larger municipalities by dewatering digested sludge, and the still larger municipalities by dewatering and drying or burning of any sludge.

Dewatering sludge on vacuum filters and burning it with garbage and refuse, either with or without pre-drying, changes the economics so that the range of the smaller municipalities which can afford disposal of sludge by burning is extended. This also applies to municipalities where garbage is ground and added to the sewage or to the digesters.

Acknowledgments

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DISCUSSION

Vacuum and Cord Filtration

By Paul O. Richter

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Vacuum Filters

As Mr. Zack has pointed out, there has been a definite increase in the number of communities being served by vacuum filters for sewage sludge dewatering. Many engineers have felt that the use of vacuum filters for the handling of sewage sludge should be restricted to communities of 25,000 or more people. Originally, because of the limited knowledge that was available on the use and operating cost of vacuum filters, this was true. However, the tendency is toward vacuum filtration in communities having populations of 7,000 and over. The problem in developing vacuum filtration equipment for the smaller communities was one reducing the initial cost and providing the operator with equipment that would not require his complete attention.

This problem brought about the design and development of the so-called package-type filter units, providing areas of 12 to 100 sq. ft. Essentially, the package unit is the same as any conventional installation, having for its basis the filter, vacuum pump, filtrate pump, and the necessary chemical feeders and conditioning tank. These items, together with all of the automatic control equipment, the interconnecting piping, and electrical starter equipment, have been grouped on a single structural steel platform so that the unit can be delivered to a job site without the necessity of making individual installations of each unit of equipment. Twelve of these package-type units are in successful operation. Reports from the field indicate that they are doing as well as their larger counterparts in communities of 50,000 and over.

The city of Detroit Lakes, Minn., has had a unit of this type in operation for approximately six years. Repairs to date have included the replacement of a ferric chloride feeder and the re-

placement of a vibrator on the lime feeder. This, of course, is in addition to the normal replacement of cloths and wire winding. The filter rate obtained on this unit with digested sludge averages about 7.5 to 8 lb. of dry weight sludge per square foot per hour. The chemical demand of the sludge averages about 1.7 per cent ferric chloride and about 7 per cent of hydrated lime, on a dry solids basis.

All of the four basic types of sludge produced by sewage treatment plants —activated, digested, raw, and chemically precipitated—can be successfully handled on a vacuum filter; all, except activated sludge, give up their water readily after the addition of certain chemicals. Because of the high cost of these chemicals, considerable study has been devoted to development of alternate chemicals for sludge conditioning. Some communities have used alum, ferric sulfate, and ferrous sulfate, but without any marked degree of success; the costs of conditioning were about the same and the results were not too satisfactory.

An attempt also has been made to set up a basis of comparison between the original cost of sludge beds and vacuum filters, and also of the operating costs of each. Although it is comparatively easy to obtain a definite cost record of vacuum filter operation, it has been difficult to obtain definite cost figures of installing and operating sludge beds, either of the open or the glass covered type. This is due primarily to the fact that, whereas the cost of building a sludge bed is definite, the cost of operation is rather flexible, as most communities use help available in other departments. Therefore, in many cases the cost of labor for removing sludge from the beds has not been charged against sludge bed operation.

Disposal of the sludge and clarification of the liquid returning to the stream constitute the main purpose of a sewage treatment plant. Therefore, vacuum filtration plus drying for fertilizer, incineration for complete disposal, or the use of filter cake for fill represents the best method of complete sludge disposal.

Cord Filters

Considerable development work has been done on the installation of the cord filter media on one of the filters operating at the Perth Amboy, N. J., plant. It is interesting to note that of the two filters operating at this plant—one with the cord attachment and one with the standard cloth cover —the cord filter constantly gives better operation, except when the standard unit is provided with a brand new filter cloth. On the cord filter, filtration takes place between the edges of the cord and not through the cord itself, as might be expected. In other words, the material used in the cord is not the critical item. However, the diameter of the cord is very important in obtaining the best filtrate clarity. Although there have been many claims made for filters of various types, it is believed that the cord filter provides a very excellent and economical attachment to any drum filter.

For some years Duluth, Minn., has operated two vacuum filters (8 ft. diameter by 10 ft. long) handling digested sludge with the addition of 1.28 per cent ferric chloride and 9.79 per cent lime, figured on a dry solids basis. The average filter cake moisture was 75.07 per cent and the daily average production of filter cake was 6,386 lb. of dry solids.

Including cost for power, all of the operating costs incidental to filter operation, and the cost of chemicals, the charges for dewatering 1,000 lb. of dry solids was $1.56, or $3.12 per dry weight ton of sludge. The Duluth records indicate that during 1948 the vacuum filter equipment produced 1,950 tons of wet filter cake having a moisture content of 75.07 per cent.

This amounted to 489.6 tons of dry weight sludge, which required 6.25 tons of ferric chloride and 47.6 tons of hydrated lime. The filter cake produced 215.3 tons of fertilizer, the remainder being disposed of by burning.

Heat Drying

By Robert D. Nickerson

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There are 18 heat drying sludge installations now operating or under construction in 14 cities in this country, most of them also equipped to incinerate in case the need should ever arise. However, the latter facility has been used so seldom that several large cities are planning to dispense with it.

Until the end of the last war, heat drying as a means of sludge disposal accounted for about 52 per cent of the total installed design capacity of all plants using either heat drying or incineration. Since then, heat drying has accounted for more than 87 per cent of all postwar capacity installed or on order. In the short space of three years, it has become the preferred method for sludge disposal.

Total tonnage sold in 1948 from all plants was about 126,000 dry tons. This represents the disposal of some 550,000 tons of filter cake. When the large Los Angeles and Houston plants go into operation, there will be a considerable increase in these totals.

The market price for heat dried sludge in 1948 varied from $5.35 to $40.00 per ton. Price depends on such factors as the type of sludge, the location of the treatment plant, market conditions, and the facilities available for bagging and bulk shipments. Digested sludge sold as high as $20.00 per ton in 1948, and activated sludge as high as $40.00 per ton. Among the advantages of heat drying as a method of disposal are the revenue derived therefrom, lower first cost for equipment, elimination of the ash disposal problem, and better public relations. There is also some conservation involved, inasmuch as the material is returned to the land.

Although the price of dried sludge is usually determined by its nitrogen and phosphoric acid content, there is a widely held belief that its humus content is the most valuable ingredient. This fact probably accounts for the price of $20.00 per ton for heat dried digested sludge on the West Coast in 1948. As soil depletion in other parts of the country becomes more severe, the price of sludge may begin to reflect the true value of the humus content.

Heat dried sludge has been found safe to use. Any doubt on this point may be resolved by reference to the Federation's Manual of Practice No. 2, "Utilization of Sewage Sludge as Fertilizer."

WARDS ISLAND PLANT CAPACITY INCREASED BY STRUCTURAL CHANGES *

By Richard H. Gould

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The Wards Island sewage treatment plant is still one of the major activated sludge plants of the world. It was placed in operation in October, 1937, and had a design capacity of 180 m.g.d. In 1938 the average flow was 169 m.g.d. Subsequently, the tributary area was enlarged; with population growth and increased water consumption, flows reaching the plant mounted rapidly. In 1947 the average flow was 226 m.g.d.; the average for the maximum month was 250 m.g.d. This heavy overload resulted in impaired operating results.

From experiences with a new type of final settling tank at Bowery Bay, and with the possibilities of step aeration (as demonstrated at Bowery Bay, Tallmans Island, and elsewhere), it was felt that much more effective utilization of existing capacities could be made at the Wards Island plant. The purpose of this paper is to outline the changes made in applying these new principles and to indicate in a preliminary way some of the improved results that have been secured.

The implication that improvements were possible is in no sense a criticism of the original design. The basis of this design was established over 20 years ago, yet it was so sound as still to be in compliance with most State Board of Health requirements, and may even have been a major element in fixing such requirements. Typical elements are:

1. Primary tanks—1-hr. detention at average rate.
2. Aeration tanks—5.25-hr. detention, with one tank out of service, at average rate plus 25 per cent return sludge.
3. Final tanks—1,000 g.p.d. per sq. ft. at 125 per cent of average flow, with 2 tanks out of service.

The plant layout and detailed development of the design is good. The plant has given excellent results and service with flows substantially above its design capacity. The original designers deserve full credit for a job well done.

Final Tanks

In studying ways and means of correcting for conditions of overload at Wards Island, it was apparent that the best chance for improvement was in the final tanks. Site restrictions and hydraulic limitations precluded the possibility of building additional tanks to receive flow from the existing aeration tanks.

There were 32 final tanks divided among 4 batteries. Each is 179 ft. long by 42.5 ft. wide. Aeration tank effluent was fed from a center conduit at the top through 6 gates. The effluent passed over weirs at both ends. Sludge was withdrawn from a hopper at the center of the tank, being scraped thereto by the conventional wooden flight and chain mechanism.

Original Current Pattern

Observations of these tanks in operation, by float tests and otherwise, made it clear that aeration tank effluent, on

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entering the tank at the center, would plunge to the bottom and flow along the tank bottom to the effluent ends, at velocities up to 6 ft. or more per min., impinge against the far wall, rise vertically, and return along the surface to the center. These currents undoubtedly were due to the greater density of the liquid carrying sludge as compared to the liquid in the tank after the sludge had settled out of suspension.

As a result of this phenomenon there was a tendency for the current rising under the effluent weirs to carry some of the lighter elements of the activated floc with it and impair the effluent. This was particularly true under high flows and with sludge of poor settling quality. A further consideration was that the bottom density currents were carrying sludge and depositing it along the tank bottom at a rate much faster than it could be removed by the collector mechanism. This resulted in blanket depths of 2 ft. or more, and it was felt that this long detention under anaerobic conditions would have an adverse effect on the settling characteristics of the sludge and increase its demand for oxygen in the aeration tank.

Tank Alterations

Alterations to correct these conditions proved to be relatively simple (Figure 1) and from present indications appear to be quite effective. It was possible to construct a reasonably adequate aerated distribution channel between the operating gallery and the final settling tanks. The pipelines carrying aeration tank effluent to the center of the final tanks were cut and diverted through a vertical riser to the new distribution channel. Three new inlet ports were cut through the adjacent end wall of each final settling tank from the distribution channel and provided with 24-in. slide gates. The effluent weirs, which formerly consisted of two iron troughs at each end of the tank and were in bad condition, were replaced with new concrete structures. At the far end of the tank there was constructed a concrete trough with plain iron weir plates on back and front. The weirs on the near side (new inlet end) were replaced with a concrete trough with a single iron weir plate on the tank side. It was provided with a wooden baffle that extended downward to a point just above the flight chains of the collector mechanism (see Figure 1). Thus, there was formed behind this weir structure a stilling chamber for the incoming aeration tank effluent. The rather substantial velocity of the incoming flow was deflected upward by an inclined baffle, which pro-

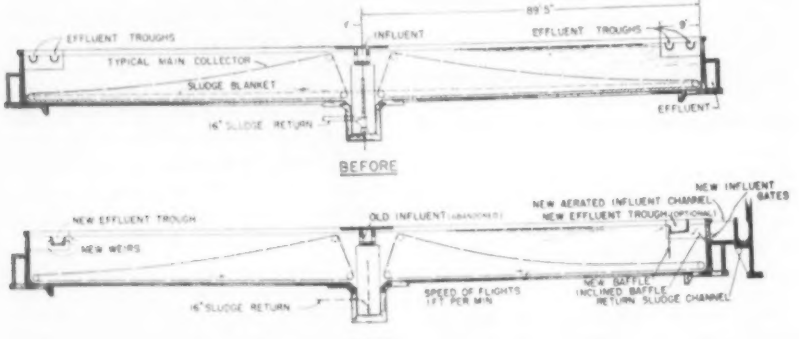

FIGURE 1.

duced sufficient turbulence at the surface to prevent scum formation in the stilling chamber and tended to dissipate much of the energy of the incoming flow.

New Distribution Channels

Air for the new distribution channel was readily secured from a line under lowered pressure that was also used for the existing return sludge channel. Three of the channels were provided with ceramic diffusion tubes and the fourth with "Precision" tubes of seran. The distribution channels provide for extra flexibility in plant operation. Formerly, an aeration tank fed 2 final tanks. Now, an aeration tank or final tank can be out of service without affecting the utility of the remaining facilities. It was not necessary to make any changes in the collector mechanisms or in the facilities for removing sludge from the tanks.

Altered Current Pattern

The incoming flow now passes under the baffle from the stilling chamber and flows rapidly along the tank bottom to the existing sludge sump that extends across the center of the tank. By the time this sump is reached, the sludge blanket is consolidated to a depth of only a few inches above the depth of the flights of the collecting mechanism. Very little of the sludge overrides the sump; practically none of it appears on the far side. The speed of travel of the sludge is indicated by the fact that dye placed in the tank influent appears with the sludge in the operating gallery in 15 min.

Under normal conditions the typical density current phenomenon appears in the inlet half of the tank. The dense currents carrying sludge flow along the bottom to the center and the clear liquid with the sludge separated out returns at the surface to the inlet end. On the far side of the tank, density currents due to sludge are not in evidence. As most of the sludge has been removed in the first half of the tank, the flow distribution in the remainder of the tank follows the familiar pattern typical of more uniformly suspended materials, such as is found in primary settling tanks.

Effect of Chlorides

At Wards Island there has been found an abnormal condition, which is believed to be peculiar to seaboard cities. In New York, sewage is intercepted from trunk sewers at a point below tide level. Tidal water is kept out of the interceptors by means of some 66 tide gates. Leakage past these gates is greater at high tide than at low tide. This results in a fluctuating chloride content of the sewage, a differential in the magnitude of 300 p.p.m. having been observed.

It originally was contemplated that $\frac{1}{3}$ of the flow would be taken over effluent weirs at the inlet end of the tank and $\frac{2}{3}$ over the weirs at the far end. It was observed, however, that when chlorides in the incoming sewage were decreasing there was a tendency for this lighter liquid to come to the surface at the inlet end, carrying with it some sludge floc. Occasionally, some of this would pass over the nearby weir. As a result of this condition, practically all the flow is now taken off at the far end of the tank and waterway passages have been enlarged to permit this. Fluctuating salt content apparently does not impair the effluent taken from the far end of the tank.

Addition of Step Aeration

The second step in the changes at the Wards Island plant was to make available the advantages of the "step aeration" method. Here again, the structural changes for its accomplishment were relatively simple and inexpensive.

The effluent from the primary settling tanks is carried through two 72

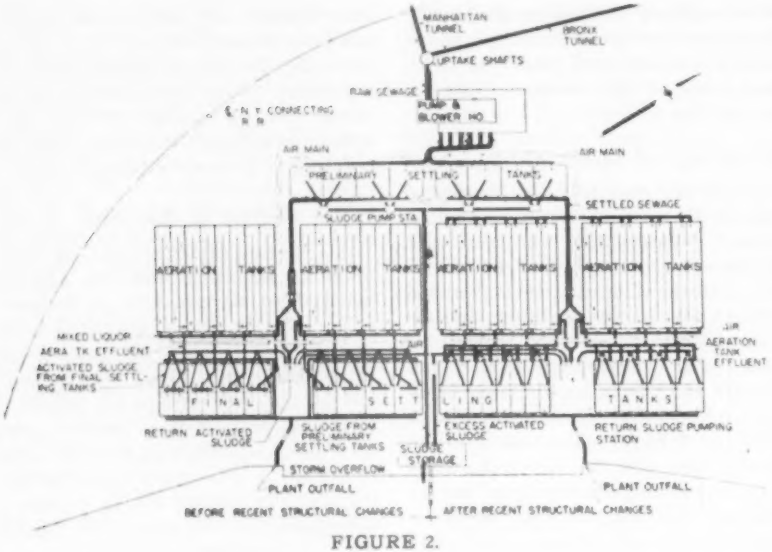

FIGURE 2.

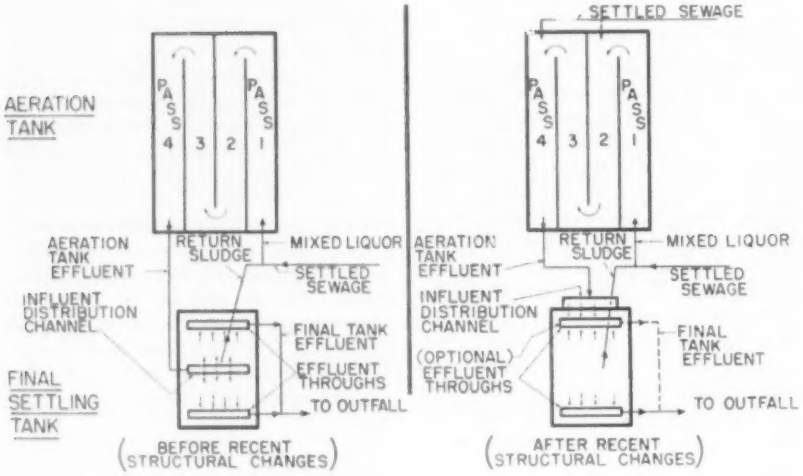

FIGURE 3.

in. conduits. Each conduit passes between two batteries of aeration tanks to a point near the operating gallery, where the flow is divided to feed each of two batteries of aeration tanks. To incorporate the facilities for step aeration, the settled sewage conduits were tapped at the west end of the aeration tanks near the primary settling tanks (see Figures 2 and 3). Connections were made to 4 new conduits built along the west end wall of the aeration tanks, the wall and extended footing of the tanks forming

one side and bottom of the conduit. Openings were cut through the end walls of the aeration tanks, leading from the new conduit to the start of the second and fourth passes of each of the 16 aeration tanks. Nozzles and 24 × 24-in. sluice gates were installed in these openings. Provisions were made so that the 4 new conduits, each serving a battery of aeration tanks, could be closed off by means of stop planks.

Increased Capacity and Flexibility

It is expected by the changes that have been made to raise the dependable capacity of the plant to 240 m.g.d. Under this condition, the 4-hr. aeration period that is available is probably adequate for good operation under normal conditions. This is particularly true in conjunction with the improved final tanks, where the activated sludge is not subject to long anaerobic detention and settling capacities are used more effectively. With a primary tank effluent of 90 p.p.m. of suspended solids, and with 25 per cent return sludge, it is only necessary to carry a concentration of solids in the aeration tanks of 1,600 p.p.m. to maintain a 4-day sludge age. This, of course, is with all units in service.

In cases, however, where the loading from the primary tanks gets out of hand, where multiple units are out of service, where the return sludge rate must be increased, or where the sludge is developing unfavorable characteristics for one reason or another, the ability to bring the step aeration technique into action is a most valuable operating control. Within an hour or so, by the simple adjustment of a few gates, the adverse situation can be started along the road to correction.

At Wards Island the operator now has the option of introducing primary tank effluent with the returned activated sludge all at the beginning of the aeration tank as in standard practice, or he may introduce the settled sewage in the proportions that conditions dictate at the beginning of the first, second, and fourth passes. For example, by admitting 50 per cent of the settled sewage at the start of the fourth pass he can reduce the circulating sludge load through the final tanks by one-third, while retaining the same sludge age. Conversely, he can add 50 per cent to the sludge age with an unchanged effluent concentration from the aeration tanks.

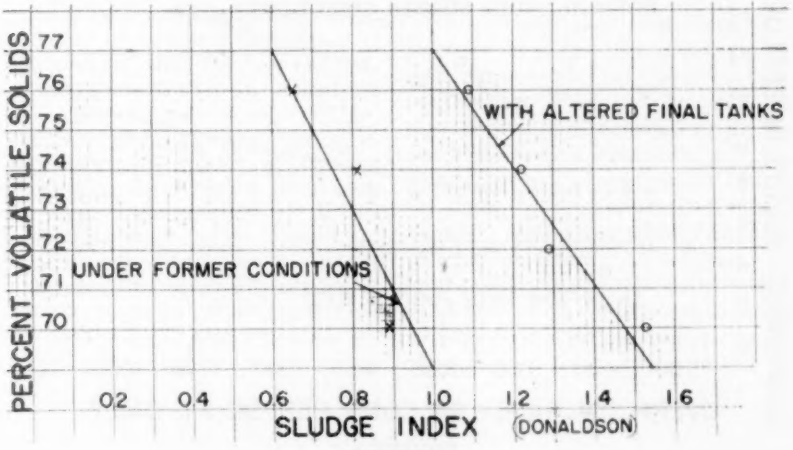

FIGURE 4.

Results of Changes

It is, perhaps, too soon to give a full accounting of the benefits that have resulted from the changes outlined. Since the changes have been completed there have been many shutdowns and shifting of units in efforts to restore a badly clogged air diffusion system. A series of mishaps to the fleet of sludge vessels at times called for unusual expedients and nonuniform plant operation. However, a few observations can be made.

An attempt was made to compare the effect of the quick removal of sludge in the altered final tanks with the old condition as it affected the sludge index, or settleability, of the activated sludge. For this purpose, the weekly averages of volatile solids in the sludge and the corresponding sludge index for 6 months prior to and 6 months after the change have been compared. It is well-known that the percentage of volatile solids is an important criterion in the resulting sludge index. The sludge indexes were, therefore, grouped and averaged in accordance with the volatile solid content of the sludge. The resulting points are plotted in Figure 4, and trend lines drawn through the points representing the old and new conditions. It is evident from this comparison that sludges of the same volatile content with the altered final tanks have substantially improved settling qualities.

The operating results for a battery operated with step aeration and with the altered final tanks for the period from June 15 through November 30, 1949, were compared with results under the old system for the same period and for the best year of record. This happened to be in 1940, before war conditions and other disrupting influences may have affected the best possible results. Under each condition, average daily results for suspended solids in the effluent were plotted against the corresponding overflow rate in the final tanks. The results (Figure 5) indicate an improvement in the final efflu-

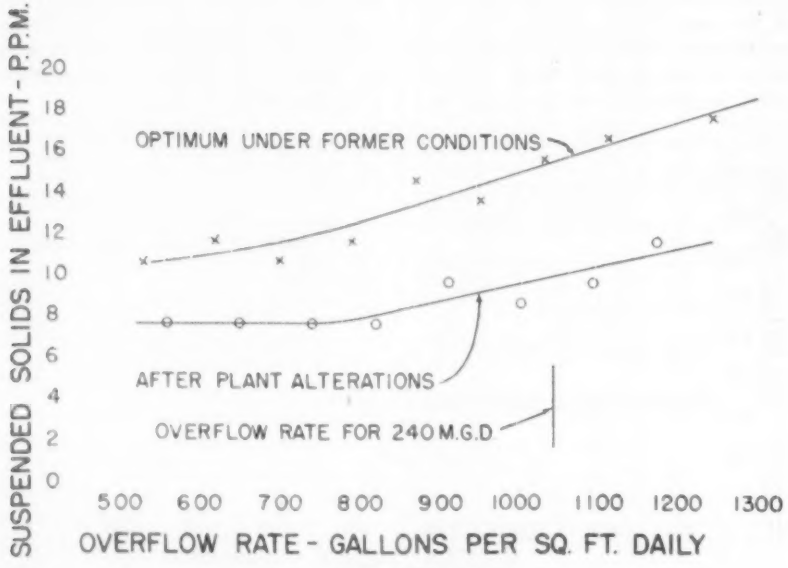

FIGURE 5.

ent under the new conditions from about 3 p.p.m. for low overflow rates to about 6 p.p.m. under higher flows. For those interested in the required length of effluent weirs, it may be noted that only about 10 ft. of weir is used per m.g. of overflow, with depths over the weir in the magnitude of 1½ in.

Cost of Alterations

The cost of the contracts for the alterations at Wards Island was: For the final tanks, $260,000; for the step aeration facilities, $134,000; or a total of $394,000. The original Wards Island project cost about $31,000,000, of which about $13,000,000 was the cost of the works on the island. This was at about the time of the lowest prewar price level. If success has been achieved in increasing the capacity of the plant from a design value of 180 m.g.d. to one of 240 m.g.d., and thus avoid providing this increased capacity in plant extensions at present day prices, the relatively small sum spent in alterations is well justified.

LIFT STATIONS IN LOW TEMPERATURE AREAS

As a part of studies undertaken by the National Research Council's Committee on Sanitary Engineering and Environment in Arctic sanitation and sanitary problems peculiar to low temperature areas, the Subcommittee on Waste Disposal recently released a report on "Sewage Pumping Stations for Low Temperature Conditions." Although primarily intended to assist in solving some of the problems encountered at military bases in these areas, the particular study covered by the report also has application outside the Arctic and at civilian installations.

After noting that there are few sewage works installations in permafrost areas, that adequate community facilities are practically non-existent in Alaska, and that existing lift stations in low temperature areas of Canada and Alaska are adaptations of conventional types used in the continental United States, the report points out the necessity for sewage pumping stations because of the flat terrain and the frost conditions. Chief difficulties associated with operation of sewage lift stations in low temperature areas have been operating failures due to freezing, pump clogging, or power outages; insufficient ventilation; flooding; and unsatisfactory maintenance due to lack of working space or hazardous conditions. Additional requirements encountered in Arctic conditions are conservation of heat loss to surrounding soil to avoid foundation failures, and provision of auxiliary heat sources to assure against inoperation of equipment.

To overcome these difficulties, particularly in permafrost areas, the report recommends that where the conventional wet well and dry well design favored for installations in the northern United States is not applicable, special consideration should be given to development of single-chamber types using storage units inside the structure. In addition, the storage chambers should be well insulated and pumps or ejector units should be selected that do not require removal of screenings in the pump station.

DISINFECTION BY SUBRESIDUAL CHLORINATION

By C. W. Beardsley

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The disinfection of sewage is a problem of growing magnitude. Increasing concentrations of population have made necessary the destruction of microorganisms on an enormous scale. Annual budgets for chlorine have mounted to hundreds of thousands of dollars, and economical use of the disinfectant has become increasingly desirable and important.

Fifteen years ago, Rudolfs, Ziemba, and Gehm (1), after an investigation of disinfection by chlorination, observed that "the greatest efficiency occurs when only ten per cent of the chlorine demand is satisfied, and that efficiency decreases as percentage satisfaction increases." This statement expresses one aspect of a problem that arises in the chlorination of sewage. Another phase may be paraphrased as follows: The uncertainty of disinfection is greatest when only a part of the chlorine demand has been met, and uncertainty decreases as the percentage satisfaction increases.

A course may be laid between the Scylla of inefficiency and the Charybdis of unreliability. The choice depends upon the end sought. If certainty of disinfection is imperative, efficiency must be sacrificed. More chlorine must be used than is necessary for disinfection. If decimation of bacteria is sufficient and funds for chlorine are limited, another line may be followed.

Clarification of Terms

In this paper the classification of chloro-reaction products as residuals and subresiduals is based on the procedure described in "Standard Methods" (2). Chloro-compounds that induce a color-forming rearrangement of ortho-tolidine in acid solution are regarded as residuals. When reference is made to a percentage chlorination, the base is the dose just sufficient to produce that change.

It should be recognized that the ortho-tolidine endpoint is an arbitrary reference point in the chlorination process. There is no basic difference in the chemical entities classed as residuals and subresiduals by this means. The bactericidal properties of the two groups grade smoothly from one into the other. A different grouping would be made by other procedures, and there is evidence that a change to another point of reference would be advantageous.

Such expressions as "bacterial kill" and "percentage disinfection" have a precise meaning only when the method by which they were determined is specified. A determination of the percentage of organisms destroyed by a disinfectant varies with the test organism and the method of assay. Different test media give widely different results. For example, a greater reduction in coliforms will be shown in chlorinated sewage by tests with brilliant-green bile agar than by tests with lactose broth.

In the results reported herein, the tests organisms have been the coliform group and the method of assay has been the confirmed test of "Standard Methods" (2). Coliforms that failed to ferment lactose were presumed to be dead, although it is probable that

the fermentation of lactose is a function that can be lost and recovered.

The dilutions used in testing for bacteria were such that, when all culture tubes proved negative, a reduction in numbers exceeding 99.7 per cent was indicated. For convenience in discussion and statistical analysis, 100 per cent destruction of bacteria has been assumed in these cases. It should be recognized, however, that a few highly resistant organisms survive unless enormous doses of disinfectant are used. In practical work, destruction of bacteria approaches, but never reaches, 100 per cent. In this paper, when bacteria have been reduced to less than 1 per cent of the original number, the sample is considered to have been disinfected.

Subresidual Chlorination at Los Angeles

A considerable volume of data with respect to subresidual chlorination has accumulated at Los Angeles' Hyperion plant during the last three years. This installation chlorinates screened sewage prior to discharge into the ocean.* For this purpose, a battery of eight large chlorinators is operated. At maximum flow these machines add chlorine to the plant effluent at a rate of 2,000 lb. per hr.

In spite of this great chlorinating capacity, the demand of the sewage is so high and the flow is so great that a residual cannot be attained at all times. For about 10 hr. of the day, subresidual chlorination is practiced in default of plant capacity to meet the chlorine demand. During this period, the chlorinators operate at their maximum rate, and partial satisfaction of the chlorine demand, in degrees ranging from 40 to 100 per cent, is obtained.

The magnitude of the operation lends significance to the data. The hourly flow of sewage is 10 to 12 m.g., and the application of chlorine is at a rate of 2,000 lb. per hr. A sufficient volume of data has accumulated to make possible interpretation by statistical methods. The inaccuracies arising from short-range fluctuations of chlorine demand, and from deviations of most probable numbers from actual numbers, are random in character. The averages of the many determinations available should be close to true values.

The data of the past three years show that a 40 per cent satisfaction of chlorine demand produces a reduction of bacteria in nearly every case. Disinfection is obtained in one-fourth of the samples. Increasing the application of chlorine increases the percentage of disinfected samples. When more than 85 per cent of the chlorine demand is satisfied, a 99 per cent reduction of bacteria is regularly obtained.

In Figure 1 subresidual data accumulated in 1948 and 1949 are summarized. Represented are 980 determinations of bacterial reduction by subresidual chlorination. The tests have been grouped and averaged in accordance with the percentages of chlorine demand that were met. Each group covers a range of 5 per cent. When surviving organisms numbered less than 1 per cent of the original count, the samples were considered disinfected.

The 80 per cent group, comprising degrees of chlorination between 78 and 82 per cent, is shown in Table I to illustrate the composition of a typical group. Bacterial kills ranging from 0 to 100 per cent were found for this degree of chlorination. Median destruction of bacteria was more than 99.7 per cent; the average was 93 per cent.

The bacterial degradation of Hyperion sewage is more advanced than is usual in most cities. Chlorine de-

* On May 15, 1950, the primary sedimentation units of the new activated sludge plant were put into operation. Complete activated sludge treatment is expected in 1951.

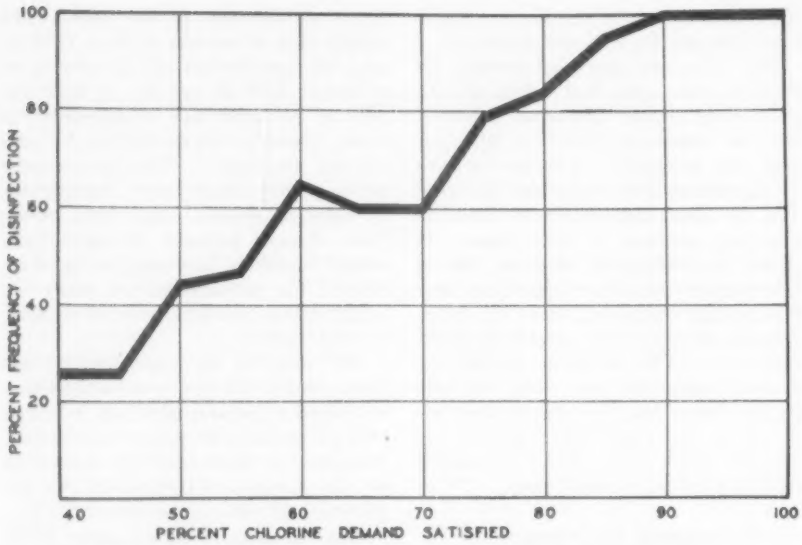

FIGURE 1.—Relation of chlorine demand satisfaction to percentage of disinfected samples.

mand averages about 30 p.p.m. in the summer months. Advanced septicity, with correspondingly high demand, is due in part to the great area from which the sewage is collected. Some of the sewage flows 50 mi. before reaching the chlorination plant. Oxygen depletion tends to be accelerated by relatively high temperatures. The summer average for Los Angeles sewage is about 80° F.

Partial chlorination is not equally effective with every type of sewage. The percentage destruction of bacteria is related not only to the fraction of the chlorine demand satisfied, but also to the amount of chlorine added. Subresidual chlorination is more likely to be effective when high demands require large amounts of chlorine.

TABLE I.—Indicated Reduction of Bacteria Resulting from 78 to 82 Per Cent Satisfaction of Chlorine Demand

Number of Samples	Bacterial Reduction (%)
4	Less than 20
0	20 to 40
1	40 to 60
5	60 to 80
12	80 to 98
110	More than 98

The test data for the Hyperion chlorination plant are a confirmation on a large scale of the findings of many investigators who have made laboratory studies of the chlorination of sewage. It has often been shown that disinfection can be obtained with less chlorine than is required to demonstrate a residual with ortho-tolidine. A consideration of the chemical mechanisms by which the destruction of bacteria is effected indicates that a high degree of correlation should not be expected.

Mode of Action of Chlorine

Although several different types of molecular structure result from the interaction of chlorine and water, bactericidal activity is largely due to a resonance hybrid, hypochlorous acid. Hypochlorous acid is represented by

the chemical formula HOCl. It is a powerful oxidant. Under standard conditions the potential of the couple, $HOCl \rightarrow Cl^-$, is 1.50 v. Hypochlorous acid is, therefore, an effective oxidizer in great dilution, and it is fast-acting because its energy of activation is low.

Resonance in molecular structures is one of the elusive concepts that have grown out of the development of quantum mechanics. The full meaning of the statement that hypochlorous acid is a resonance hybrid cannot be discussed in this paper. A first approximation to understanding may be obtained, however, if the molecule is thought of as resonating from one electronic configuration to another with inconceivable rapidity. From one of these configurations it replaces hydrogen in carbon and nitrogen compounds with chlorine; from another configuration hydrogen is replaced by hydroxyl. A tendency to oxidize by chlorination and a competing tendency to oxidize by hydroxylation are, therefore, latent in the same molecule.

In biological systems, vital enzymes are engaged in irreversible reactions by compounds that oxidize by chlorination. Such oxidation becomes lethal at certain levels of oxidation potential. It is not the oxidation potential that is lethal, however, but the intensity of a type of oxidation that is associated with the halogens. Other strong oxidants produce no bactericidal effect that is comparable to the action of chlorine. Hydroxylation is lethal only at much higher levels of oxidation potential.

The germicidal superiority of chlorine is apparent when it is compared with oxygen. At a pressure of 30 atm. the oxidizing power of oxygen approximates that of chlorine in the concentrations that are used for the disinfection of sewage. Oxygen is relatively nontoxic to aerobic microorganisms at this concentration. In a series of tests, the author found only a slight reduction of coliforms in sewage when pH was reduced to 5.0 and oxygen pressure was maintained at 30 atm. for 15 min.

Tests with other strong oxidants, such as potassium permanganate and hydrogen peroxide, have shown that, although they are not without bactericidal effect, none is comparable to chlorine in lethal power. The destruction of bacteria in chlorinated sewage is not simply a matter of oxidation potential. Disinfection results from oxidation by chlorine, for the lethal power of chlorine resides in the structure of the atom itself.

The hybrid nature of hypochlorous acid manifests itself in its action on living organisms. As it acts either by chlorination or by hydroxylation, a lethal and a nonlethal proclivity are united in a single structure. It approaches the bacterial cell in the role of a chemical Jekyll and Hyde. The outreaching valence may be that of oxygen, the preserver, or of chlorine, the destroyer.

The issue of a lethal or a nonlethal reaction is not wholly a matter of chance. There are determinants in sewage that orient a trend toward one type of reaction or the other. It is probable that pH, temperature, oxidation-reduction potential, and dissolved oxygen exert a directing influence, but these do not account for the anomalies of subresidual chlorination. Other factors appear to determine the dominant type of oxidation that will occur. Reactions that link chlorine to carbon or nitrogen preserve the lethal power of the chlorine and transmit it to the reaction products. When the trend is toward hydroxylation the build-up of bactericidal action is slower.

Differences in the Chemistry of Water and Sewage Chlorination

In water treatment, the first increments of chlorine react with traces of ammonia to form chloramines. This

reaction continues until chlorine, equivalent to 5 times the ammonia content of the water, has been added. The antibacterial action of the chlorine increases up to this point, which is called the "hump." Increments of chlorine beyond the hump initiate reactions in which the chloramines are converted to nontoxic substances. Bactericidal activity declines as the chloramines are destroyed and almost disappears at the break-point. This point is reached when chlorine equivalent to about 10 times the original ammonia content of the water has been added. Increments of chlorine beyond the break-point produce a highly effective residual of free chlorine. Break-point chlorination is generally considered desirable, although in the process germicidal compounds are built up and destroyed again.

Ammonia nitrogen is present in sewage in amounts of 20 p.p.m. or more. Such concentrations make break-point chlorination impracticable, as enormous chlorine dosages would be required to obtain a free chlorine residual. Such doses are quite unnecessary. The chlorinated organic compounds that provide bactericidal action in sewage are quite adequate for disinfection. They are present in a variety and concentration never found in water supplies. They are effective in the presence of organic matter, and their action is enhanced by soaps, detergents, and other surface tension depressants that are always present in sewage.

A succession of compounds of varying lethal potency is formed when chlorine is added to sewage in increasing amounts. The phenomenon of rising and declining bactericidal effect that appears in the chlorination of water may sometimes be observed. The "humps" in sewage are not well defined because of overlapping action among a number of antibacterial substances. Bactericidal effect often rises unevenly, however, in a series of humps and sags as potent bactericides are formed and destroyed.

The irregular build-up of lethal effect with increasing doses of chlorine is illustrated by the curves of Figure 2. An ideal curve for water containing ammonia in solution (Figure 2a) is characterized by a single hump and a single break-point. Sewage, which is a system of many components, is represented by Figure 2b, in which a hump marks the culmination of each rising phase of bactericidal action.

Maxima of antibacterial action occur in Hyperion sewage when 30 to 60 per cent of the chlorine demand has

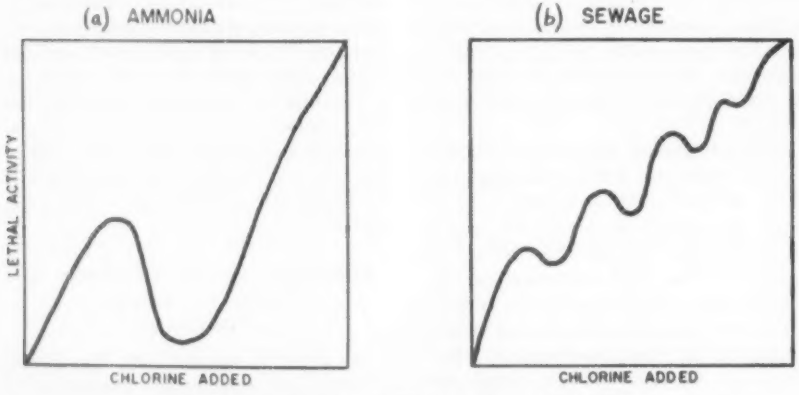

FIGURE 2.—Irregular build-up of bactericidal action.

been satisfied. These early maxima are elusive. Their existence can be demonstrated, but the chlorine dosage that produces them can be determined only by time-consuming biological assays. Chlorination at this level is attended by undue risk of failure. Reasonably reliable maxima of antibacterial action are found when 80 to 90 per cent of the chlorine demand has been met. In the proximity of these peaks lethal potential is great enough to decimate the bacteria when the most effective dose has been missed. Chlorination maintained at this level will regularly destroy more than 95 per cent of the coliforms.

Inadequacy of Indicators

It is probable that indicators for lethal activity cannot be found. Color production by indicators is derived from such properties as tautomerism and polarity. Toxicity is related to quite another set of properties. Such indicators as benzidene, ortho-tolidine, and para-amino-dimethyl aniline contain a phenyl ring that is shifted from a benzoid to a quinoid structure by oxidation. This chromogenic rearrangement is produced by some, but not all, of the chloramines. Oxidation-reduction potential appears to be only one of the factors that determine whether color formation will occur. Molecular configuration is probably another. In certain cases the slow rate of color formation suggests that steric hindrance may be operative.

Catalysis also influences the rate and course of the reaction. Marks and Joiner (3) found that ortho-tolidine reacts with certain of the chloramines at a rate that is independent of concentration, and that, in these cases, the color developed is not a measure of reactivity. When working with the spot plate technic, a spot will sometimes be observed that initiates color development very slowly and then rapidly develops full color. Such a change of rate is suggestive of autocatalytic action.

Better measures of antibacterial action might be obtained with indicators other than ortho-tolidine. Unfortunately, satisfactory oxidation-reduction indicators are relatively rare. Indicators for pH are found in several classes of organic compounds, but no such latitude of choice is available for oxidation-reduction titrations. Most of the useful indicators for oxidation reactions are found in the meriquinone group of compounds. Ortho-tolidine is a typical meriquinone and its faults are the general faults of the group. One defect is that it is an indicator for pH as well as for oxidation-reduction potential. The colored modification passes through shades of blue, green, red, and yellow in the pH range from 7 to 2. A stable color of unvarying shade is obtainable only by adding a great excess of acid. Such massive acidification overthrows and eradicates the reaction patterns that normally develop in sewage chlorination.

Conclusion

When sewage is treated with increasing amounts of chlorine, inflection points are passed where the trend of reaction shifts from a lethal to a nonlethal type. Such critical points may correspond to the initiation or completion of specific reactions, or to the attainment of critical levels of oxidation potential. Further increments of chlorine accelerate hydroxylation reactions, which destroy bactericidal substances previously formed.

Reaction trends are dictated by the chemical characteristics of the sewage. In some cases, reactions of the lethal type appear to be catalytically accelerated by substances that are incidentally present, for antibacterial action builds up rapidly. Such effluents can

be disinfected by partial chlorination. Wasteful hydroxylation reaction sequences may be reduced by careful control of chlorine dosage.

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INSERVICE TRAINING COURSE IN PLUMBING PROBLEMS

A second inservice training course in Plumbing Problems will be offered by the School of Public Health, University of Michigan, on September 15 and 16, 1950, at Ann Arbor, Mich. This is the thirty-sixth in a series of inservice, non-credit, training courses offered by the University's School of Public Health.

The course, which is being given at the suggestion of workers in the field of study of the problems, is planned to develop some of the fundamental considerations involved in the more established practices, as well as in newer problems that assume significance in plumbing practice. A primary intention of the course is to develop plumbers and sanitarians to the point where they can conduct similar seminars in their local communities, thus enabling a vastly greater number to benefit by the exchange of ideas and experience with current problems.

Major topics to be covered include hydraulic principles; safety precautions and devices, particularly with regard to flammable and toxic gases and liquids; plumbing problems involved in disposal of trade wastes, with particular reference to waste surveys, waste characteristics, and maintenance of equipment and controls; fundamentals governing septic tank design and installation; and developments in the formulation of a national uniform plumbing code.

SEWAGE RECLAMATION AT FRESNO, CALIFORNIA *

By A. Segel

Deputy Commissioner of Public Works and City Engineer, Fresno, Calif.

It has been said that sewage water reclamation is as old as sewage disposal itself, but the modern or recent use of the term implies that treated sewage effluents are put to beneficial uses, rather than being merely wasted into a river or the sea. Until recent years, the kinds of beneficial uses have been very few. The one outstanding use has been in agriculture. This is especially true in the western states, and particularly in California.

The central valley of California, where the City of Fresno is located, is now also becoming aware of the water shortage problem within its own borders. The reclamation of sewage water may, therefore, become of greater importance in this inland agricultural area in the years to come.

It is interesting to note that in California there are about 42 cities and towns which use treated sewage effluents for the irrigation of crops. The City of Fresno, with a population of about 110,000 inside the city limits, is by far the largest of the cities making use of the effluent for this purpose, and has done so for many years.

Fresno owns and operates a municipal farm, 1,292 acres in area, located about 5 mi. southwest of the city. This is also the site of the recently installed primary sewage treatment plant. The acreage is now segregated into uses and crops approximately as follows:

Use or Crop	Area (acres)
Alfalfa	65
Sudan grass	90
Kaffir corn	190
Grass pasture	600
Lagoons	305
Ranch and plant yards, etc.	43
Total	1,292

On the farm there are over 600 head of fine Hereford cattle. Until more land is purchased, however, it is not likely that this number will be increased. This, then, is the area on which disposal is made of an average flow of 18 m.g.d., or 55 acre-ft. per day.

The combination farm and treatment plant set-up has been quite profitable for several years past, in that an operating profit has resulted. For instance, in the fiscal year ending June 30, 1949, the total operating cost and expense of the farm and treatment plant was $46,001, whereas the total cash income of the farm and plant for the same period was $55,347, showing an operating profit of $9,346.

With the planned enlargement of the cropping area, as against the pasture and lagoon areas, and the proper selection of types of crops, it is entirely possible that the operating profit will, in the future, pay a substantial rate of interest on the capital investment.

The above discussion has been based on the successful use, of late years, of the effluent on the land by means of ordinary irrigation methods. Looking back to 1921, however, the conditions were quite different.

In that year, Fresno found itself in

* Presented at 22nd Annual Meeting, California Sewage Works Assn.; Long Beach, Calif.; May 3–6, 1950.

a critical situation with reference to the disposition of the sewage effluent. At that time, the city owned only 812 acres, but the bad feature was that the ground-water level was only about 2 ft. below the ground surface. Law suits were filed by adjacent landowners against the city for waterlogging and flooding adjacent lands.

After some experimentation, the city lagooned some of the land and installed 9 drainage wells 200 to 300 ft. deep with no perforation of the casing less than 100 ft. from the surface. The wells were very successful in lowering the water table so that rapid percolation into the soil could take place. The clear water from these scattered wells was collected and diverted to the Fresno Irrigation District for use in its system.

However, conditions have materially changed so that for the past two or three years, these wells and pumps have been idle. It is quite possible that they will never again be used for underdrainage purposes, the main reason being that the area surrounding the municipal farm has now been developed for agricultural crops, accompanied by the installation of many irrigation wells. The resulting general lowering of the ground-water level has created a condition which does not interfere with percolation of the plant effluent into the underground basin.

As to the future, no one can accurately predict, but considering the ever-increasing scarcity of water, the treatment plant effluent is a valuable asset, whether diverted for irrigation purposes to others or used by the city as at present.

SEWAGE RECLAMATION AT MELBOURNE, AUSTRALIA *

By Charles Gilman Hyde

Consulting Engineer, Berkeley, Calif.

Information concerning sewage reclamation in Australia has been made only sparingly available to American engineers. The outstanding project, and possibly the only one of special interest, appears to be that of the metropolitan area of Melbourne. The material in this paper is largely based on abstracts, published from time to time in *Sewage Works Journal*, of the annual reports of the Melbourne and Metropolitan Board of Works.

Area, Climatic Conditions, and Population of Australia

Australia is by far the largest single island mass on the earth's surface; so large that it is recognized as a continent. Its area is very closely 3,000,000 sq. mi.; almost precisely that of the United States. Moreover, its over-all dimensions are quite similar to those of the United States.

In latitude, south, it extends approximately from 11° to 39°. Its climate is tropical in the north and temperate in the south. In the Southern Hemisphere, Melbourne, on the continent's southeast coast, has closely the same latitude (38°) as does San Francisco in the Northern Hemisphere. There are but three river systems of significant size. The western half of the continent is almost rainless.

The estimated total population of Australia in 1945 was 7,365,000, of which fully 80 per cent live in the three eastern states of New South Wales, Victoria, and Queensland, named in the order of their respective populations. In 1812, the population of the United States was closely that of Australia today.

Melbourne Metropolitan Sewerage District in 1938

The metropolitan area of Melbourne, in 1938, comprised 438 sq.mi. containing 26 municipalities and portions of 12 others. At that time, 96 sq. mi. were sewered on the separate system. The sewered population was 1,039,600, living in 261,800 premises, and constituting about 95 per cent of the entire population of the district.

The annual rainfall in the District was reported to range from 17.3 to 25.6 in., according to geographical location.

The sewage flow was reported then to average about 58 m.g.d. (U. S.), with a dry weather volume of 56 m.g.d., or about 58 and 56 g.e.p.d., respectively.

Melbourne Metropolitan Sewerage District in 1948

By 1948 the population of the District had increased about 20 per cent. The original plans, prepared in 1891, provided for a population of 1,000,000. By 1946 the population had grown to such an extent that it was proposed to develop a system of sewerage to serve a total population of 2,000,000.

The Melbourne and Metropolitan Board of Works has established a policy under which sewers will be provided for areas having a population of

* Presented at 22nd Annual Meeting, California Sewage Works Assn.; Long Beach, Calif.; May 3–6, 1950.

TABLE I.—Statistics of Sewerage and Sewage Disposal of the Metropolitan Area of Melbourne, Australia

Year	Sewered Population	Premises Sewered	Sewage Farm Area (acres)	Cattle on Farm[1]	Sheep on Farm
1937–38	1,040,000	262,000	22,630	—	—
1939–40	1,090,000	275,000	—	—	49,600 [2]
1941–42	1,140,000	286,000	—	—	66,000[3]
1943–44	1,140,000	—	23,790	—	11,600[4]
1945–46	—	—	24,580	14,300	—
1946–47	—	—	24,580	13,500	—
1947–48	1,230,000	310,000	24,610	13,200	—

4 persons per acre, regarded as one-fourth developed.

Industrial wastes account for about 22.5 per cent of the normal week-day dry flow, and of the cost of collection and disposal. The industrial charge is $1.61 per 12,000 gal. (U. S.) of waste, with a minimum annual charge of $16.14. Industries are encouraged to spread their discharge by a discount of 2.5 per cent for every 5 per cent by which the ratio of maximum hourly discharge to mean hourly discharge is less than 4 to 1, provided that in no case shall the discount exceed 30 per cent. The levy is based on water use because of the difficulty of measuring the wastes themselves.

Melbourne Sewer Farm

The sewer farm of the Metropolitan Sewerage District is described as being located 24 mi. outside the city. Most of the sewage requires pumping, and has an average age of 16 hr. on arrival at the farm. It is stale and highly corrosive to structures. The farm area in 1938 was 22,634 acres; in 1948, 24,610 acres, an increase of about 9 per cent. The cost of the farm, as of 1939–40, is estimated to have been approximately $4,220,000, or $186 per acre.

The farm receives over 99 per cent of the sewage flow of the District. There are two small sewage treatment plants, which served 7,100 and 5,600 persons, respectively, in 1942.

In 1938 a grass pasture of 9,425 acres was irrigated at the rate of 1,200,000 g.p.d. (U. S.), or at a rate of only about 130 g.p.d. per acre. Cattle, sheep, and horses were allowed to graze thereon 5 days after watering. As of that date, grass filtration was reported as being carried on in special bays 33 ft. wide and upwards of 1,200 ft. long, in which the growth

TABLE I *(continued)*

Year	Farm Income[5] ($)	Net Cost of Sewage Treatment ($)		
		Annual Total	Per Capita	Per M.G. (U.S.) (approx.)
1937–38	—	—	—	—
1939–40	261,000	$265,000	$0.24	$11.50
1941–42	375,000	44,000	0.04	1.75
1943–44	195,000	252,000	0.22	10.00
1945–46	152,000	380,000	0.32	14.60
1946–47	—	394,000	0.34	15.00
1947–48	288,000	440,000	0.36	16.30

[1] At end of year. [2] Purchased. [3] Sold. [4] Temporarily cared for because of extensive destruction by fire of grazing lands in Victoria. [5] From sale of live stock, skins, hides, wool, etc.

of grass was heavy. After one year, a rate of loading was reached that did not exceed 60,000 g.p.d. (U. S.) per acre. Presedimentation has not been provided.

The sewer farm is now largely used for raising and fattening cattle. At times in the past, especially during the late war, sheep raising was resorted to because the Commonwealth Government would not permit the sale of cattle raised on sewage irrigated land to be sold for human consumption.

During 1946, 1947, and 1948, the number of cattle on the farm averaged about 13,700, representing approximately 1.8 gross acres per head.

By 1947, during the 55 years of existence of the farm, established in or about 1892, 600,000 seedling trees had been planted, principally eucalyptus and pines.

Assuming a contribution of 60 g.c.p.d. (U. S.), a contributing population of 1,250,000 persons, and a gross area of 24,600 acres, it will be seen that the average minimum rate of sewage disposal is of the order of 3,000 g.p.d. per acre. The actual acreage on which sewage is being disposed is not presently known.

Table I reflects some of the principal features of farm operation, including costs, during the 10-year period from 1937–38 to 1947–48.

ACCIDENT PREVENTION FOR PUBLIC EMPLOYEES

The Public Employee Safety Committee of the National Safety Council will hold its third annual meeting at the Stevens Hotel, Chicago, Ill., on October 16, 1950. This session is part of the annual National Safety Congress and Exposition.

Marvin L. Davis, director of public service, City of Akron, Ohio, will talk on how to overcome obstacles in applying industrial safety methods to public employment. Mr. Davis' remarks will be of substantial help to public employers who would like to profit by the high degree of safety and efficiency achieved by many safety programs in private industry.

One of the most ambitious city-wide, centrally organized municipal safety programs in the country is that recently undertaken by the Bureau of the Budget for the City of New York. Alfred R. Lateiner, consulting director, New York City Accident Control Program, and a member of the staff of New York University, will discuss the training of city and state supervisors for safety.

An informal panel discussion with audience participation will be conducted on the general subject of "Chance Taking on Small Jobs." The purpose of the free-for-all will be to uncover the specific problems of the audience and panel members in the control of unsafe practices on types of work not usually subject to careful preplanning. The panel discussion will be led by H. D. Jones, director, Safety Department, State Highway and Public Works Commission, North Carolina.

Industrial Wastes

CHARACTERISTICS OF INDUSTRIAL SEWAGE IN THE RARITAN RIVER VALLEY*

By Willem Rudolfs and H. Heukelekian

Most published studies dealing with the treatment of mixtures of domestic sewage and industrial wastes are concerned with the behavior and effect of such mixtures after a treatment plant has been constructed. Some published studies deal with the behavior of sewage and waste mixtures when discharged into receiving fresh waters. Still others deal with the discharge of sewage into salt water. An unusual opportunity was provided to predetermine the approximate nature and behavior of mixed wastes that would result from the collection, treatment, and disposal of all municipal and industrial wastes in the Raritan River Valley in connection with a trunk sewer project proposed by the Middlesex County (N. J.) Planning Board.

The proposed Raritan River trunk sewer project consists of the collection of all municipal and industrial wastes into a sewer some 22 mi. long and terminating at a joint treatment plant consisting of sedimentation and chlorination with provision of discharging the effluent into Raritan Bay at a point where proper dispersion, dilution, and passage into the ocean will be assured. Tentatively, sludge disposal consists of barging it to sea.

There are 14 sewage treatment plants in the valley, serving 18 municipalities. For the purpose of this study 10 of the major industries discharging wastes, but not discharging into municipal sewers, were included. These major industries consist of asbestos products, chemicals and dyes, yeast fermentation, cigarette paper manufacturing, photographic film production, finishing materials, paint pigment, gun powder, and plastics.

Specific questions requiring preliminary answers were as follows:

1. The pH value of the mixed wastes at different sections of the sewer (to select suitable materials for the construction of a sewer to protect it from corrosion).
2. The strength and characteristics of the mixed wastes received at the treatment plant.
3. The expected removals at the treatment plant.
4. The chlorine demand of the mixed wastes.
5. The volume, quantity, compaction, and dewaterability of sludge produced from the mixed wastes.
6. The quantities of sludge, B.O.D., and chlorine demand of the important industrial wastes contributed to the system by the participating industries (for tentative development of a formula for the allocation of cost).
7. The behavior of effluent in and the effect on the receiving salt water.

Methods

Samples of wastes produced from the important industries were obtained and neutralized to a pH value of 4.0, if necessary, on the assumption that

* Paper of the Journal Series, N. J. Agricultural Experiment Station, Department of Sanitation, Rutgers University, New Brunswick, N. J.

when all mineral acid is neutralized and the wastes are mixed with domestic sewage no corrosion problems will be encountered. One of the municipal treatment plants includes large volumes of industrial wastes; separate samples were obtained from this source. Mixtures were made with these various samples on the basis of existing known flows. The flows from all the municipal plants in the valley, with the one exception noted above, were represented in the mixture by one typical domestic sewage.

The mixtures were made by using a volume of domestic sewage corresponding to the flow of sewage from all the municipalities and each of the 10 major wastes produced by industries according to the percentage of each in the total combined flow. The following determinations were made on the mixtures: pH; settleable solids, suspended solids, and B.O.D. before and after settling; coliform organisms and chlorine demand after settling; deoxygenation effect of the settled effluent; and solids concentration, volume, quantity, compacting, and dewaterability of the sludges. On the industrial wastes, the following determinations were made: pH, lime requirements of the acid wastes, B.O.D., and chlorine demand.

Findings

Wastes Volumes and Characteristics

The volumes and characteristics of the wastes are shown in Table I. The volumes of the wastes produced vary from 0.085 to 31 m.g.d. with a total volume of 100.8 m.g.d., of which 74.0 m.g.d. is contributed by industrial wastes exclusive of those discharged into municipal sewers. The municipal plant included as a separate item in this study was receiving large volumes of industrial wastes with a pH value of 10.0. The pH values of the industrial wastes show wide variations (from 2.7 to 11.5). Some of the industries neutralize the wastes before discharge. The amount of lime required to accomplish this objective is not pertinent to this study.

The B.O.D.'s of the wastes range from 60 to 2,660 p.p.m.; however, the total pounds of B.O.D. discharged are more pertinent, as some of the wastes with relatively low B.O.D. concentration have high flows and others with

TABLE I.—Volumes and Characteristics of Wastes

Waste No.	Flow (m.g.d.)	pH	B.O.D.		Susp. Solids		Sludge Volume (ml./l.)	Chlorine Demand	
			(p.p.m.)	(lb./day)	(p.p.m.)	(lb./day)		(p.p.m.)	(lb./day)
1	6.0	10.6	60	3,000	435	21,750	18	13	650
2	20.0	4.6	160	26,560	62	10,290	2.1	38	6,300
3	0.085	11.5	2,250	1,590	52	35	18.0	7.5	5
4	0.25	9.1	2,660	5,500	1,745	3,490	8.5	235	485
5	0.60	5.9	2,400	12,000	260	1,300	trace	190	950
6	6.0	10.7	355	18,750	333	16,650	29	19	945
7	0.12	2.8	1,635	1,630	25	25	trace	18	18
8	0.10	6.5	1,000	830	70	55	1.2	2.6	2
9	2.5	3.5	147	2,930	8	160	trace	7.8	160
10	7.5	5.0	315	19,500	288	17,850	2.1	84	5,225
11	31.0	2.7	38	7,965	186	47,800	2,810	37	9,520
12[1]	9.0	10.0	410	30,600	413	30,975	40.0	16	1,200
13[2]	17.7	6.8	220	33,440	185	28,120	3.0	5	760
Total	100.8	—	—	172,485	—	183,200	—	—	25,950

[1] Municipal sewage containing large volumes of industrial wastes.
[2] Strictly domestic sewage.

TABLE II.—Efficiency of Suspended Solids Removal from Various Wastes by Quiescent Sedimentation

Waste No.	Removal (%)	Waste No.	Removal (%)
1	88	8	34
2	69	9	—
3	52	10	79
4	—	11	99
5	57	12	72
6	41	13	76
7	56		

high B.O.D. concentration have low flows. The B.O.D. contributed by individual industrial wastes varies from 830 lb. to 26,560 lb. per day. The domestic sewage contains 67,000 lb. B.O.D. part of which is also due to industrial wastes. The total B.O.D. contributed amounted to 172,500 lb., of which a minimum of 60 per cent is due to industrial wastes. The population of the lower Raritan drainage area is about 255,000 according to the 1940 census, whereas the population equivalent of the combined wastes, on a B.O.D. basis, is about 1,000,000. Industrial wastes, on this basis, constitute 75 per cent of the population equivalent. The suspended solids produced by industry are at least 68 per cent of the total.

With certain wastes, considerable difficulty was encountered in the determination of chlorine demand because of the color interference, pH effect, etc. Accordingly, some of the chlorine demand values were obtained on the basis of starch iodide residual; others by the ortho-tolidine tests. The chlorine demands given in Table I are approximations. Of the total 26,000-lb. chlorine demand of the materials discharged, at least 75 per cent is attributable to industrial wastes.

In assessing the suspended solids removed by sedimentation, a constant factor of removal cannot be used for various wastes, as indicated in Table II. The percentage removals of individual wastes varied from as low as 34 to as high as 99 per cent. Therefore, in assessing the solids removal by sedimentation, the suspended solids contributed by each waste (Table I) must be multiplied by the respective efficiency of removal upon sedimentation (Table II). On the basis of the values given, the calculated indicated quantity of suspended solids removed from all the wastes by sedimentation is 144,560 lb., or an over-all efficiency of 79 per cent on the basis of individual industrial wastes. This does not take into account the possible interaction of various wastes resulting in higher or lower removals, depending on the nature of the various wastes. Therefore, as indicated below, the actual amounts removed at the treatment plant may be at variance with the individual values.

A similar difficulty arises in assessing the chlorine demand of the industrial wastes. If the chlorine demand is determined before the wastes are settled or mixed together, an entirely different value may be obtained from that determined after the mixture has been settled.

Characteristics of Wastes Mixture

The mixture of wastes, made as they would enter the trunk sewer, showed that the lowest pH value would prevail at the upper end of the sewer, increasing progressively from 5.0 to 5.9 at the lower end of the sewer. This is the result of the nature and volume

TABLE III.—Characteristics of the Artificial Mixture

Sludge volume (ml./l.)	27
Suspended solids, before settling (p.p.m.)	259
Suspended solids, after settling (p.p.m.)	29
Suspended solids removed (%)	89
Ash in suspended solids (%)	59.5
Suspended solids, before settling (lb.)	215,000
Suspended solids, after settling (lb.)	24,000
Suspended solids removed (lb.)	191,000
B.O.D., before settling (p.p.m.)	190
B.O.D., after settling (p.p.m.)	150
B.O.D., before settling (lb.)	159,200
B.O.D., after settling (lb.)	125,700
B.O.D. removed by settling (lb.)	33,500
B.O.D. removed (%)	21
Chlorine demand, after settling (p.p.m.)	18.4
Chlorine demand, after settling (lb.)	15,275
Coliform organisms (1,000/ml.)	10–250

of the wastes and of domestic sewage discharged at different points. These values are based on neutralization of the acid wastes to pH 4.0 before discharge.

The characteristics of the artificial mixture are given in Table III. The composite mixtures produced a sludge volume of 27 ml. per l. after 1-hr. quiescent sedimentation in Imhoff cones. It is apparent that a much larger volume of sludge is produced from the mixture of these wastes than from domestic sewage. The strength of the mixture, as indicated by suspended solids, is not excessively high and corresponds to a strong domestic sewage. Exceptionally high removals (89 per cent) were obtained by sedimentation of the mixture. This is to be compared with an indicated removal of 79 per cent on the basis of removals obtained by each individual waste before mixture, and a maximum of 60 per cent for domestic sewage when settled for 1 hr. Thus, a much greater removal of suspended solids is obtained by sedimentation of the wastes before mixing than in domestic sewage, and an even greater removal is obtained when all the wastes are mixed with domestic sewage. The effect is due to acids and iron compounds present in some of the wastes, corresponding to highly effective chemical treatment. There is a distinct advantage in treating these wastes in a central plant as compared to individual treatment.

The greater removals result in greater sludge production, amounting to 191,000 lb. of dry suspended solids as compared with 144,560 lb. obtained as the sum of removals by the individual wastes before mixing, or a sludge production of about 2,000 lb. per m.g. of mixture. The sum of the suspended solids in the individual wastes was 183,200 lb., whereas that calculated on the basis of the actual mixture was 215,000 lb., a difference of 31,800 lb. or a variation of approximately 16 per cent, which is beyond the experimental error of this determination and signifies that effective coagulation takes place when the wastes are mixed.

The B.O.D. value of 190 p.p.m. is that of an average sewage. The removal by sedimentation amounts to 21 per cent, which is lower than that obtained by sedimentation of domestic sewage. A total of 159,000 lb. of B.O.D. was present in the mixture before settling, as compared with 172,500 as obtained from the sum of each individual component before mixing (Table I). The two methods of arriving at the B.O.D. contributed are within 13,500 lb. of each other, a variation of approximately 4 per cent, or within the experimental error of the determination. This appears to indicate that little or no soluble organic material present in some of the industrial wastes was precipitated, as compared with effective coagulation of the suspended solids.

The chlorine demand of the mixture after settling was equivalent to 15,275 lb., as compared with the sum of the chlorine demand of each waste of 26,000 lb. As the experimental error of this test may be high, it is not known whether this difference is significant or whether it indicates an actual decrease of chlorine demand caused by mixing of the individual wastes and settling. However, the greater removal of suspended solids from the mixtures would indicate a corresponding reduction in chlorine demand of the effluent.

The determinations of coliform organisms of the effluent from the mixed wastes after settling gave values of 10,000 to 250,000 per ml., indicating a possible removal and destruction of these organisms.

Characteristics of Sludge

The ash content of the suspended solids in the various industrial wastes is, with few exceptions, very high. The exceptions consist of those indus-

TABLE IV.—Effect of Effluent on the Initial D.O. Level

Conc. of Mixed Settled Effluent (%)	Dissolved Oxygen (p.p.m.)		
	0 Min.	30 Min.	60 Min.
0	8.5	—	—
3.3	8.5	8.5	8.3
6.6	8.3	8.2	8.3
10.0	8.0	8.0	8.0
20	7.6	7.3	7.4

tries whose wastes are relatively small in volume and suspended solids. Industries discharging large volumes of wastes contribute large quantities of suspended solids with high percentages (60 to 80 per cent) of ash in the suspended solids. Accordingly, the suspended solids of the composite wastes had an ash content of 59.5 per cent. The sludge formed from the sedimentation of such a waste contains a high percentage (64 per cent) of ash and should compact and dewater readily. Such was actually the case. The volume reduction of sludge by compacting for 8 hr. amounted to 80 per cent. A solids content of 5 per cent or more was readily attainable. The sludge dewatered readily under vacuum without the addition of chemicals and with a moisture content in the cake of 76.5 per cent. The addition of lime or ferric chloride did not improve the rate of filtration or decrease the moisture content of the cake.

Oxygen Demand of Settled Effluent

The presence of reducing substances (such as sulfides, sulfites, and ferrous sulfate) in some of the wastes made it desirable to determine whether the waste, when discharged into the bay, would exert an immediate high rate of oxygen demand. The settled effluent was diluted in various proportions with standard dilution B.O.D. water, and dissolved oxygen determined initially and after 30 and 60 min. by the sodium azide modification of the Winkler method. The results obtained (Table IV) show that the higher concentrations of the waste exert an immediate effect on the dissolved oxygen level. The dissolved oxygen level after 30 and 60 min. did not decrease for a given concentration of the waste. It is safe to conclude that the initial depression of the D.O. level with high concentrations of the waste is not caused by actual deoxygenation, but rather by interference with the determination and by low D.O. of the effluent. There is apparently no high rate of demand exerted.

The long-time oxygen demand of the waste effluent was studied at 5 per cent concentration using standard dilution water, as well as sea water diluted with distilled water in 1 : 1 ratio. The daily B.O.D. values are shown in Figure 1. The deoxygenation rate in diluted sea water is somewhat lower during the first two days of incubation than in standard dilution water; thereafter, the rate in the two types of water is approximately the same.

The presence of some inhibiting substances in the wastes is evidenced by the following 5-day B.O.D. values of the various concentrations of the waste diluted with the standard B.O.D. dilution water:

Waste Conc. (%)	B.O.D., 5-Day (p.p.m.)
0.8	168
1.7	156
3.3	130
5.0	118
7.0	110

The decreasing B.O.D. with increasing concentration of the waste indicates the presence of inhibiting substances.

The results indicate, in general, that at the point of discharge of the settled effluent in the bay the deoxygenation effect will be minimal because of high dilution and slow rate of deoxygenation.

After-Flocculation

The settled liquor was mixed with diluted salt bay water (1 : 1) in 10 and

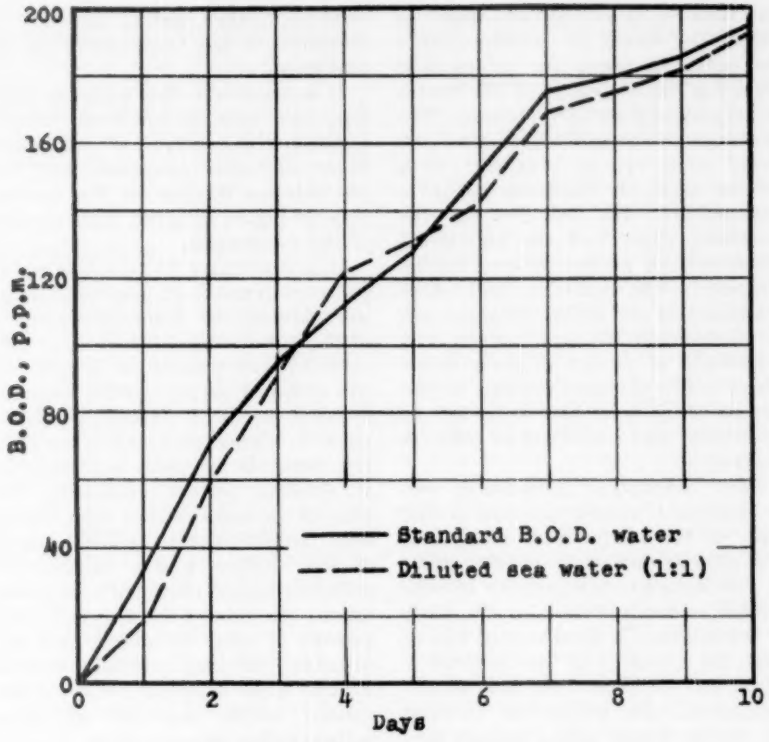

FIGURE 1.—B.O.D. of mixed waste effluent.

20 per cent concentrations (by volume) in an effort to simulate the conditions in the bay and study the possibility of after-flocculation of the effluent at the point of discharge. The mixtures were allowed to settle and the volume of sludge formed in Imhoff cones was determined. There was no immediate flocculation of solids, but after 24-hr. storage 0.16 per cent of sludge was formed in the 20 per cent mixture of effluent in sea water. The slow rate of formation of the fine floc would, therefore, insure the dispersion of the material and prevent the formation of localized sludge deposits.

Discussion

In dealing with a problem of this nature prior to the construction of a sewer for the collection of large volumes of industrial wastes with different characteristics, predictions as to the nature, characteristics, and behavior of the ensuing mixture obviously cannot be made on the basis of experience from domestic sewage. A scheme of preliminary study as outlined in this paper is necessary and will give valuable information for estimating treatment plant unit capacities and aid in the design of the sewer and treatment plant facilities. It is essential, for a study of this nature, to know the flows from each major source, whether industrial or domestic, so that the mixtures can be made on the basis of proportionate flows. Samples obtained should be representative of each waste. They

can then be mixed, in the order in which they would be discharged into the projected sewer, for information regarding the character of the wastes in various sections of the sewer. The approximate strength of the total collected waste can be obtained. If a certain type of treatment plant is contemplated, the efficiency of the treatment plant and the pollutional characteristics of the effluent can be estimated. The quantity and characteristics of the sludge obtained can be studied and the type, nature, and magnitude of sludge disposal determined. The chlorine demand of the effluent will give an idea of the size of chlorinator and quantities of chlorine required.

Other interesting information can be obtained if results obtained on the basis of the mixtures are compared with those of each separate component. If, for instance, the quantity of suspended solids estimated on the basis of the mixture is significantly higher than the quantity of the suspended solids derived from the total of the components, an interaction between the various wastes with resultant precipitation of solids is indicated. It is of interest that, in the present instance, the total quantity of B.O.D. obtained by the two methods was within the experimental error of the determination; in other words, the interaction and precipitation did not materially affect the organic matter, but was mainly restricted to the inorganic constituents.

An interesting question arises from the discrepancy of the solids balance between the two methods. In assessing the cost of construction and operation of the sludge treatment facilities, each contributor ordinarily would be charged according to the quantity of solids contributed, based on the analysis and flow of the individual waste. However, sludge production at the treatment plant might be higher than that derived from all the contributors combined. How should the cost of treatment of this excess sludge be apportioned?

It is conceivable that a similar situation may arise in the total chlorine demand requirements of the wastes before and after admixture, and that the chlorine demand of the mixture may be higher or lower than the sum of the components.

It is interesting to note that an 89 per cent removal of suspended solids was obtained by plain sedimentation of the mixed wastes, whereas an indicated over-all removal of 79 per cent was obtained on the basis of sedimentation of each waste separately. Either value is higher than the corresponding removals by plain sedimentation of domestic sewage, indicating that some of the wastes settled more readily than domestic sewage, and that mixing of the various wastes together resulted in higher efficiency of sedimentation. In view of the fact that large volumes of waste containing high concentration of iron salts are contributed, it is not surprising that the suspended solids removals by plain sedimentation are equivalent to those to be expected from effective chemical treatment.

Summary and Conclusions

A survey was made of the character, quantity, and behavior of individual wastes and ensuing mixtures of wastes contributed by various major industries and municipalities to a projected trunk sewer in the Raritan River Valley in N. J. Suspended solids, B.O.D., pH, and chlorine demand of the individual wastes and of the proportionate mixture were determined before and after settling, and the effect of settled effluent on the receiving salt water was assayed. The results show that:

1. The pH values of the mixed wastes in the trunk sewer would not be less than 5.0, and might be as high as 5.9 in the lower section, provided

that wastes with low pH values were neutralized to pH 4.0 before discharge.

2. Most of the major industrial wastes are acid in nature.

3. The percentage contributions of industries as compared with municipalities were:

	Industry	Municipalities
Flow	75	25
B.O.D.	61	39
Population equivalent	75	25
Suspended solids	68	32

4. It appears that formation of suspended solids from materials in solution takes place as a result of interaction of various types of wastes.

5. Sedimentation of the individual wastes showed an indicated over-all removal of 79 per cent of suspended solids, whereas the sedimentation of the mixtures gave an 89 per cent removal, indicating the benefits derived from treatment of the wastes collectively as compared with individual treatment.

6. The sludge volumes and quantities were higher than would be expected from domestic sewage, but the solids were mostly inorganic and, accordingly, compacted and dewatered readily without the addition of chemicals.

7. Difficulties can be expected in assaying the chlorine demand if the usual methods are applied to industrial wastes.

8. The mixed waste effluent after sedimentation did not manifest a rapid short-time oxygen demand. Substantially the same B.O.D. values were obtained with standard dilution water as with diluted sea water (1:1). The mixed waste effluent had a tendency to give lower B.O.D. values with higher concentrations, indicating the presence of inhibitory substances.

9. No appreciable after-flocculation of the settled effluent would occur when discharged into the salt (bay) water.

10. In the absence of a common collecting sewer, the value of an artificial mixture made according to flows is shown for predicting the characteristics of the mixed wastes, their response to treatment, the character of the effluent, and the effect of the effluent on the receiving body of water.

SIGNIFICANT CHARACTERISTICS OF SEWAGE AND INDUSTRIAL WASTES *

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Within the last two years much progress is evident in the extension of both fundamental and practical knowledge of the characteristics of sewage and industrial wastes. Many researches in analytical methods financed from federal grants are now bearing fruit, and critical reviews of analytical methods, as well as articles on newly proposed procedures, abound in the technical periodicals.

In the face of this flurry of scientific activity, there is noted a tendency on the part of many who are engaged in the design and operation of treatment works to overlook certain time-proven tools useful in evaluating the characteristics of sewage and industrial waste. The 5-day B.O.D. and the suspended solids values alone do not depict the behavior of sewage, yet these often are the only criteria given serious attention.

This paper considers several other characteristics of sewage and industrial wastes and their significance in the design and operation of treatment works. The discussion is limited to characteristics disclosed by the determinations for total and volatile solids, settleable solids, B.O.D. removed by settling, and by the relation of the 1-day B.O.D. to the 5-day B.O.D. Data are taken from several sources to illustrate the range of values which may be encountered, and examples are cited of the application of these characteristics.

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Total and Volatile Solids

Total solids and total volatile solids content of sewage and wastes long have been standard measures of strength. Nevertheless, for many recent investigations and reports of operation, these values either have not been determined, or for other reasons have not been reported in the published data. This omission is particularly noted in the literature on industrial wastes, despite the fact that in many industries substantially all of the material lost in processing can be accounted for by the total and volatile solids in the sewage.

In contrast, B.O.D. is an inconsistent and, to laymen, incomprehensible measure of material losses. Likewise, the suspended solids test fails when the waste contains a large proportion of solids in the dissolved state. The total solids content represents the suspended, colloidal, and dissolved material to be dealt with and is, after correction for the mineral content of the water supply, a primary measure of strength of sewage or waste. For these reasons, the total and volatile solids determinations ought to be included in all investigations, in analyses of plant operation, and in reports thereof.

Total solids values do not vary with the time and place of sampling, whereas the relationship between the suspended and the colloidal and dissolved components may undergo great change. This was strikingly illustrated during the course of studies preliminary to the design of the San Jose, Calif., sewage treatment works. In the lab-

oratory, two portions of diced trim from fresh pears (peel and core) were placed in distilled water and stirred; one portion for 15 min., the other for 2 hr. After 15 min. of stirring, two-thirds of the total solids were present as suspended matter and could be removed by settling. After 2 hr. of stirring, one-third of the total solids were present as suspended matter. Thus, the leaching of soluble matter from the suspended particles in a 2-hr. period reduced their weight by one-half.

The B.O.D. of a sewage or organic waste is closely related to the total volatile solids in the waste, the exact proportion depending on the degree of oxidation of the organic matter and on its availability as bacterial food. The relationship for normal domestic sewage is approximately 0.37 lb. of 5-day B.O.D. per pound of volatile solids (1). Studies of characteristics of milk waste by Trebler (2), Eldridge (3), and others show a range of 0.82 to 0.85 lb. of 5-day B.O.D. per pound of organic solids in skim milk, whole milk, and various whole milk products. For whey and cream these investigators report values of 0.55 and 0.88, respectively. Through researches on the disposal of paper mill wastes, the B.O.D. of the several components of sulfite liquor have been determined (4). Data are also available on the B.O.D. of many pure organic substances. Recently, it has been proposed to use certain of these pure substances as primary standards for the B.O.D. determination (5).

Very little information is available concerning the B.O.D.-volatile solids ratio of cannery wastes, even though such factors would often be convenient tools in coping with the immense problem of the disposal of cannery waste in California. During the 1949 canning season, a program of sampling was carried out at the San Jose outfall sewer. Fifteen canneries having a total production of 2,500 to 5,400 tons of raw fruit per day are tributary to the sewer. The average values for the B.O.D., the volatile solids, and the B.O.D.-volatile solids ratio resulting from this study are as follows:

Type of Pack	Pounds per Ton of Fruit Processed		
	B.O.D.	Vol. Sol.	B.O.D./ Vol. Sol.
Peach and pear	34	39	0.87
Pear and tomato	25	30	0.84
Tomato	9	11	0.82

Ratios obtained by analysis of wastes from individual canneries in the San Joaquin Valley had the following range of values:

Waste	Ratio of B.O.D. to Vol. Sol.
Apricot	0.77
Peach	0.86 to 0.92
Tomato	0.77 to 1.08

From a thorough laboratory study of solid wastes or garbage from fruit canning, the following ratios were obtained (6):

Solid Waste	Ratio of B.O.D. to		
	Total Vol. Sol.	Settl. Vol. Sol.	Diss. Vol. Sol.
Peach	0.65	0.40	0.81
Pear	0.50	0.20	0.67
Tomato	0.44	0.56	0.38

These values show that volatile nonsettleable solids of peach and pear waste, pound for pound, exert a greater B.O.D. than the volatile settleable solids. The reverse is true in the case of the tomato waste.

Settleable Solids

Settleable solids may be determined either by volume, using the Imhoff cone, or by weight. In the latter method, the suspended solids are determined by filtering both before and after quiescent settling, and the difference in amount of suspended matter

is taken as the settleable solids. The test by weight is one of practical value because it simulates full-scale sedimentation. The results permit the estimation of the performance of sedimentation tanks and the loading on sludge disposal facilities. For control of plant operation, the simple volumetric measurement of settleable solids may never be entirely replaced by the determination by weight. Nevertheless, the latter is more effective, for instance, in determining whether abnormal performance is caused by a change in sewage characteristics, or by the design or conditions of operation of the plant. By suitable modification of the procedure the effect of plain flocculation may be included in the determination. From mathematical analysis of the studies made in connection with the sewage survey of the East Bay Cities in 1940 (7), Ludwig (8) has proposed a modification of the test to provide 15 min. of stirring followed by 20 min. settling, in lieu of 2 hr. of settling. His studies indicate that the ultimate removals of suspended solids and B.O.D. were obtained by this method.

The fraction of suspended solids which will settle in 1 to 2 hr. varies through a considerable range, and may be affected by strength and age of the sewage and by the mineral content of the water supply, as well as the presence of industrial wastes. The average settleable solids value for 16 samples taken from 8 sewers of the East Bay Cities was 48 per cent of the suspended solids content of 340 p.p.m. (7). The ultimate value (which theoretically would be attained at an infinite period of settling) appeared to be 56 per cent of the suspended solids. The latter may be compared with a mean ultimate value of 71 per cent of the suspended solids for sewage at six military installations (9). At the Richmond-Sunset plant in San Francisco, the average removal of suspended solids by plain flocculation and sedimentation was 73 per cent for the year 1948–49 (10).

The suspended matter in waste from the canning of fruit settles readily. Settleable solids, expressed as per cent of suspended solids, usually exceeds 85 per cent for screened apricot, peach, and tomato wastes. In the combined domestic sewage and cannery waste from San Jose prior to and during the 1949 canning season, the settleable solids were as follows:

Month	Principal Packs	Susp. Sol. (p.p.m.)	Settl. Sol. (2 hr.)	
			(p.p.m.)	(% of susp. sol.)
June	Minimum canning	330	260	78
July	Apricot	360	270	75
Aug.	Peach and pear	570	500	88
Sept.	Pear and tomato	350	300	86
Oct.	Tomato	320	270	84

At San Jose during August and September the suspended matter showed settling characteristics very similar to those of activated sludge. After 15 to 20 min. of settling, the turbidity of the supernatant generally appeared to be as low as at the end of 2 hr. After collection of the sample, large floc formed immediately; this was followed by rapid settling and, finally, the settled sludge compacted at a very slow rate. In these tests settleable solids were determined by volume, as well as by weight, and the solids content of the sludge was computed therefrom.

The present procedure for the determination of settleable solids (11) was proposed as a standard method by

Fischer and Symons in 1944 after three years of trial at Buffalo (12). The prior standard method, which involved the determination of total solids of the settled sludge, did not gain general acceptance. With greater use, either of the present procedure, or preferably that proposed by Ludwig in the event that it is found generally applicable, it would be desirable to express the performance of sedimentation units on the basis of settleable solids, rather than on suspended solids. Thus, comparisons of efficiency of settling tanks of different design or volumetric loading would not be obscured by variation in the settleability of the suspended matter.

B.O.D. Removed by Settling

The fraction of B.O.D. removed upon settling sewage or industrial waste is comparable in significance to settleable solids. As in the test for the latter, it is determined as the difference between the B.O.D. before and after quiescent settling. Thus, B.O.D. removed by settling is that exerted by the settleable solids. The proportion of this fraction to the B.O.D. of the raw sewage is affected not only by the settleability of the suspended organic matter, but also by the relative amount of organic matter in solution. Hence, the removal of B.O.D. by primary sedimentation varies over a wider range than does the removal of suspended matter.

Results of B.O.D. removal by primary sedimentation at 26 municipal plants reported by Keefer (13) show an average value of 35 per cent. The average B.O.D. of the raw sewage at these plants was 230 p.p.m. For stronger sewages, removals are commonly in excess of 40 per cent. Removals of 50 to 55 per cent are normally attained at the Richmond-Sunset plant in San Francisco, which receives a fresh, almost entirely domestic, sewage (10).

However, if primary removal assumed in design proves to be too high, or if substantial changes in the sewage characteristics occur, overloading of secondary treatment facilities may result. This was illustrated on a broad scale early in the war at sewage treatment plants at Army posts. Based on the meager information then available, plant design criteria in 1940 were based on an anticipated B.O.D. removal of 50 per cent by primary settling. By the end of 1941 sufficient operating data were accumulated to indicate that the removal, on the average, would not exceed 35 per cent. At the same time, it was observed that the B.O.D. contribution per capita was about 0.20 lb. per day, instead of the expected 0.17 lb. The combination of these two factors resulted in a 50 per cent greater loading on secondary units; that is, 0.13 lb. per capita, in place of 0.085 lb. Subsequently, design criteria were modified to take these characteristics into account.

The presence of industrial wastes, under some conditions, may tend to increase the removal of B.O.D. by settling. More often, removal is greatly reduced because a substantial portion of the B.O.D. is exerted by matter in a soluble or colloidal state. Examples of B.O.D. removal by 2-hr. settling (in the laboratory) are given in Table I for a variety of wastes and combinations of sewage and waste, arranged in order of the degree of removal obtained. Obviously, materials such as molasses stillage, consisting almost entirely of solubles, yield no reduction on settling. Less than 10 per cent removal was noted for well-screened apricot, milk, and cattle-slaughtering waste. B.O.D. removals of 10 to 20 per cent were obtained for many food processing wastes, either alone or with domestic sewage. High removals were obtained only for a few of the wastes, notably those having a high content of fibrous matter.

As in the case of settleable solids, it would be desirable and far more

TABLE I.—Removal of B.O.D. from Industrial Wastes by Sedimentation

Waste	Five-Day B.O.D.		
	Raw (p.p.m.)	Settled[1] (p.p.m.)	Removal (%)
Molasses stillage[2]	37,600	—	0
Apricot[3, 4]	1,205	1,170	3
General creamery[5]	1,090	1,010	7
Cattle slaughtering[5]	780	700	9
Itendering, sardine[5]	33,800	30,200	11
Potato[3, 4, 6]	930	830	11
Spinach[5]	540	450	12
Dom. sewage, molasses, and end liquor	860	750	13
Dom. sewage, peach, and pear[2]	1,120	980	13
Pear trim, macerated[5]	—	—	14
Brewery vat waste[5]	730	630	14
Prune tenderizing[5]	2,000	1,700	15
Sheep slaughtering[5]	610	560	18
Dom. sewage, pear, and tomato[2]	740	610	18
Dom. sewage, apricot[2]	700	570	19
Dom. sewage, tomato[2]	450	320	19
Dom. sewage, molasses stillage[2]	510	400	21
Peach trim, macerated[5]	—	—	25
Potato[3, 6]	1,350	990	27
Chrome tannery[3]	800	560	30
Normal domestic sewage	230	150	35
Hominy[5]	460	330	39
Wool pulling[5]	1,180	690	41
Tomato trim, macerated[5]	—	—	43
Rendering, meat[5]	6,800	3,850	43
Roofing, paper[5]	98	54	45
Asparagus[5, 7]	1,150	100	88

[1] Settled 2 hr.
[2] From unpublished studies of sewage from San Jose, Calif.
[3] From unpublished reports on wastes from industries in Turlock, Manteca, and South San Francisco, Calif.
[4] After passing 20-mesh screen.
[5] Reference 7.
[6] From potato chip factory; abrasive peeling process used.
[7] Asparagus butts macerated.
[8] From potato dehydrator; lye peeling process used.

realistic to compare the performance of sedimentation facilities on the basis of settleable B.O.D., rather than on the total B.O.D. of the sewage or waste.

Rate of B.O.D. Reaction

In using the 5-day B.O.D. at 20° C. as a measure of sewage and waste strength and as fundamental loading factor for treatment works and receiving waters, possible deviations from the commonly accepted normal rate of reaction should not be overlooked. It is possible that material deviations occur more often than have been suspected in the past, and that these may account for anomalous performance of treatment works and localized depletion of oxygen in streams.

Significance of the velocity constant, k, in the unimolecular B.O.D. equation, $y = L(1 - 10^{-kt})$, may be appreciated if, in this atomic age, terminology applied to radioactivity is used. The release of energy from radioactive substances follows the unimolecular law, which has been found to be applicable to the first-stage B.O.D. reaction. However, in place of expressing the velocity of reaction by means of the k

value, the term "half-life" is used. Thus, a radioactive isotope may have a half-life of, say, 10 days (or 10 min.), at which time one-half of the energy has been released. Similarly, at the normal k value of 0.1 for the B.O.D. reaction, the half-life is 3 days (that is, one-half of the ultimate B.O.D. is exerted within this time). Examination of the B.O.D. equation will reveal that the half-life is inversely proportional to the k value. Thus, the half-life for a k value of 0.2 is 1.5 days; for 0.3, 1 day. Caldwell and Langelier (14) have suggested the term "half-ultimate" B.O.D. to express the reaction velocity as a function of time.

Determination of the velocity constant k of the B.O.D. equation requires that the B.O.D. exerted daily over a period of 5 to 10 days be measured. Recently, Thomas (15) has presented a short-cut method for determining the approximate k and L (ultimate B.O.D.) values from the laboratory data. Nevertheless, routine investigations seldom provide for the additional laboratory work involved.

For exploratory purposes, an indication of the value of k may be obtained simply by determining the 1-day and 5-day B.O.D.'s. At the normal reaction rate, k equals 0.1, the 1-day and 5-day B.O.D.'s are, respectively, 20.6 and 68 per cent of the ultimate first-stage B.O.D. Thus, the 1-day B.O.D. is 30 per cent of the 5-day B.O.D.

Figure 1 shows graphically the ratio of the 1-day B.O.D. to the 5-day B.O.D. and to the ultimate B.O.D. for k values ranging from 0.025 to 0.6. It will be seen that the 1-day B.O.D. is 0.25 of the 5-day B.O.D. at a k value of 0.05, and 0.4, 0.5, and 0.6 for k values of 0.2, 0.3, and 0.4, respectively. Also shown is the ratio of the 5-day B.O.D. to the ultimate B.O.D. for the same range of k values. At a k value of 0.2, 0.9 of the ultimate B.O.D. theoretically would be exerted in 5 days, whereas at a k of 0.4 or higher, 0.99 or more of the ultimate value would be attained. In computing these values, it is assumed that the reaction proceeds in accordance with the unimolecular equation and that the ultimate value, L, remains constant. Although neither assumption may be entirely correct in specific instances, the approximate magnitude of the k value can be obtained from the principal curve in Figure 1.

In practice, the 1-day B.O.D. obtained by the standard dilution technique is likely to give a low value, either because of initial lag in bacterial development, or because of the effect of toxic substances in the lower dilutions than those employed for the 5-day B.O.D. test. Therefore, when seeding of industrial waste is necessary, a substantial portion of settled sewage should be employed to prevent initial lag, hence, low results for the 1-day test. Likewise, the number and range of dilutions should be sufficient to show whether or not toxic substances cause interference.

Manometric methods for the determination of B.O.D. offer a distinct advantage when it is desirable to plot the course of the B.O.D. curve (14). Readings may be made with ease and at any desired interval of time. It has been found, however, that for identical samples higher velocity constants are obtained with the manometric procedure than when using the standard dilution technique. Hence, comparison of velocity constants must be restricted to those obtained by similar laboratory procedure.

The extent of possible variation of the k value was illustrated in the National Research Council report on "Sewage Treatment at Military Installations" (9). The average k value for grab samples analyzed at 16 military posts was 0.18, and ranged from 0.10 to an extreme of 0.30. These high values ordinarily would not be expected in a sewage containing little, if any, industrial waste. Although military sewage is, in general, stronger

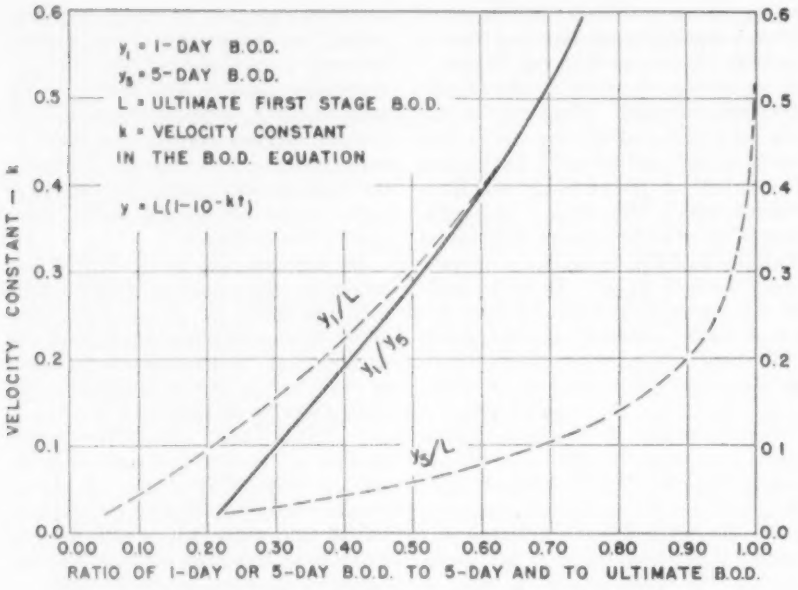

FIGURE 1.—Relation of k to 1-day and 5-day B.O.D.

than normal municipal sewage, no correlation between strength and k value was found. For the cases cited, strength ranged from 185 p.p.m. to 677 p.p.m. of 5-day B.O.D. Subsequently, Ruehhoft (16) made a further investigation of the velocity constant in sewage from domestic, institutional, and military sources, which indicated that the normal k value may be nearer 0.15 than 0.10. Lesser k values were obtained when high dilutions were employed, and were attributed to the onset of nitrification within 3 to 7 days of incubation.

When industrial wastes are present, much higher values of k may be encountered. An example, which may be extreme, is the B.O.D. exerted by end liquor, a waste remaining after the extraction of monosodium glutamate from concentrated Steffens waste of the beet sugar industry. End liquor has a volatile solids content of 48 per cent, and a 5-day B.O.D. of 380,000 p.p.m. by weight. It is probably the strongest liquid waste ever discharged in quantity to a municipal sewer system. At San Jose, the average of 78 tons (14,300 gal.) of end liquor discharged each day has a population equivalent of 350,000. Because of the significance of this waste to the design of treatment works, a thorough study of the B.O.D. was made.

The B.O.D. curve for the end liquor, plotted in Figure 2 from the average values of five series of tests, indicates the possible existence of two rates of oxidation. The B.O.D. exerted during the first 12 hr. after the initial lag period appears to have a k value of 0.57 and would have an ultimate B.O.D. of 463,000 p.p.m. if the reaction continued as indicated by the upper dashed line. After 12 hr. the curve assumes a k value of 0.31 and has an ultimate B.O.D. of 400,000 p.p.m. The nitrifying stage was evident in dilutions incubated beyond 5 days.

During a program of sampling of combined sewage and industrial waste from the San Jose outfall from June through October, 1949, the 1-day B.O.D. of the settled sewage was routinely determined. Throughout this period, the 1-day B.O.D. quite consistently was 60 per cent of the 5-day B.O.D., although average monthly values of the latter varied from 620 p.p.m. during the tomato canning season to 1,230 p.p.m. during the peach and pear canning season. Although the picture was obscured by the presence of end liquor in the sewage, available data indicated that the peach and pear waste had a k value in the range of 0.3 to 0.4, whereas the tomato waste had a value of about 0.1. In view of the velocity constant reflected by the high 1-day B.O.D. during the peach and pear pack, it is planned to dilute the settled sewage at the inlet of the oxidation ponds with recirculated pond effluent in the ratio of 10 : 1, in lieu of 5 : 1 as originally proposed.

When sewage or waste having a high velocity of oxidation is discharged to a stream, it is obvious that a more rapid and greater depletion of oxygen will occur than would be expected on the basis of the 5-day B.O.D. of the sewage. Likewise, it would be difficult to maintain aerobic conditions at the inlet end of an oxidation pond unless ample dilution and dispersion were provided. The difficulties encountered in maintaining dissolved oxygen in contact aeration plants and with bulking sludge in activated sludge plants at military posts may have been in large part caused by high rates of the B.O.D. reaction. At the Camp Claiborne activated sludge plant, which later reported a k value of 0.3, a battery of 20 mechanical aerators could not cope with the sewage until a preliminary filter was installed. In trickling filters, the effect of high k values on performance is probably less pronounced than in other forms of secondary treatment, due to their ability to withstand shock loads.

In view of the ease of adding the 1-day B.O.D. test to routine laboratory analyses of sewage and wastes, it is desirable to include this determination in investigations of sewage and industrial waste characteristics and at suitable intervals in routine plant control tests. When significant deviation from the normal rate of the B.O.D. reaction

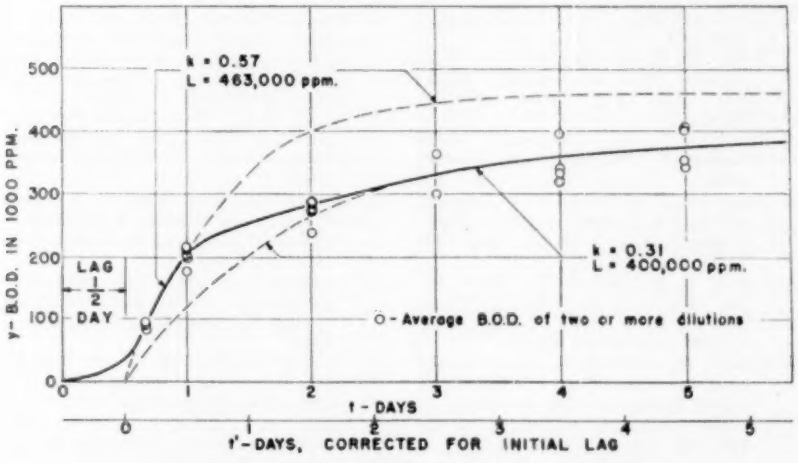
k = 0.57
L = 463,000 ppm.
k = 0.31
L = 400,000 ppm.
LAG 1/2 DAY
O - Average B.O.D. of two or more dilutions
y - B.O.D. IN 1000 PPM.
t - DAYS
t' - DAYS, CORRECTED FOR INITIAL LAG

FIGURE 2.—B.O.D. (20°C.) of beet sugar end liquor.

is indicated by the relation between the 1-day and 5-day tests, a more thorough investigation of the velocity of the B.O.D. reaction is in order.

Summary

Although great strides are now being made in the determination and evaluation of the characteristics of sewage and industrial wastes, in practice there is a tendency to regard the 5-day B.O.D. and suspended solids as the sole criteria of strength and behavior. In many cases, particularly where industrial wastes are a factor, further inquiry into the nature of the sewage or waste will reveal characteristics of fundamental significance to the design of treatment works and to the evaluation and control of their performance.

In considering a few of these characteristics, it is noted that the total solids tests of industrial wastes directly reveal all losses of material to the sewer, and, therefore, are often of great interest to the industrialist. The relation of the B.O.D. to the total organic matter is a useful tool in dealing with wastes from the food processing industry.

The determination of settleable solids by weight merits greater attention, both in preliminary investigations and in evaluation of plant performance. Likewise, the determination of the B.O.D. after settling is of value in estimating the removal which may or should be obtained. Wide variations from normal B.O.D. removal may be encountered, as cited by examples, and if not anticipated may cause an overload on secondary treatment facilities or on receiving waters.

Deviations from normal in the rate of the B.O.D. reaction may occur more frequently than has been suspected. A high rate of oxygen utilization manifestly has an adverse effect on disposal by dilution and on oxidation ponds, and may be a factor in substandard performance of other secondary treatment processes. For exploratory purposes, the velocity constant, k, of the B.O.D. equation can be estimated simply from the ratio of the 1-day to the 5-day B.O.D. More thorough analyses are warranted when significant deviations are encountered.

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INDUSTRIAL WASTES IN MUNICIPAL SEWERS

Because of the extreme interest in and extensive discussion of matters pertaining to admission of industrial wastes into municipal sewers, the Council of the South African Branch, Institute of Sewage Purification, has prepared a memorandum expressing its views in this regard. It is pointed out that the recommendations do not constitute a definite policy, but are intended, with modifications to suit local or specific conditions, to be of assistance to local authorities wishing to regulate acceptance of industrial wastes and the charges for such service.

The recommendations concerning domestic sewage and wastes from existing or proposed industries are as follows:

1. A local authority should be prepared to take the whole of the town's water-borne wastes, domestic and industrial, into its sewerage system for treatment, within the limits of safe functioning of its sewers and sewage disposal works.

2. It should be understood, however, that a local authority retains the right to refuse admission of certain industrial wastes, on account of their danger to health, damage to sewers, or not being amenable to treatment, or on account of the wastes placing an unreasonable load on the existing treatment facilities.

3. It is necessary to draw attention to the need for the local authority to plan ahead and provide adequate treatment for the community's water-borne wastes.

4. The local authority shall have the right to charge for the acceptance and treatment of industrial waste without prejudice to any sewer or other conventional fees.

5. The charges for industrial waste disposal should be in relation to the waste load contributed by the industry.

6. The charge levied against an industry for the load contributed should not be made with a view to profit or loss, but should be based on the established cost price of treatment of the mixed sewage entering the works.

7. The preceding clauses do not in any way debar the local authority from granting a rebate on the industrial waste charges.

8. The local authority should prescribe, where necessary, a minimum pretreatment of the industrial waste to make the condition thereof compatible with the safety of the main sewer, the sewage disposal works, and structures connected therewith.

9. In the case of proposed industries, the local authority should insist on the submission by the industry of all relevant information, and of a sample typifying the anticipated industrial waste. Such a sample, and the anticipated daily discharge volume, should enable the local authority to decide whether it will accept the industry, and under what conditions.

10. There should be at least a measure of regional uniformity among local authorities with regard to their policies for acceptance and treatment of industrial wastes.

HIGH-RATE ANAEROBIC DIGESTION OF INDUSTRIAL WASTES *

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The term "high-rate anaerobic digestion" is employed by the authors to describe this process rather than the more scientifically correct one used by Buswell (3)—that is, "methane fermentation"—as it is felt that the former implies a waste treatment process, and the latter a process carried on with the purpose of producing an end product of commercial importance. As the methane produced is seldom in excess of that required to meet inherent thermal requirements, and the process is basically identical to the sewage sludge digestion process, the former is perhaps the best descriptive term as far as the waste treatment field is concerned.

This item is brought forth because one of the purposes of this paper is to demonstrate the difficulty of comparing past results of both research and practice, due to variations in nomenclature and analyses employed, and to plead for standard terms for expressing results obtained so that various projects can be better compared and evaluated. A further purpose is to point out the extent of progress in the development of high-rate anaerobic digestion and the advances responsible for this progress; also to suggest a procedure likely to lead to improved efficiency and broader application. In doing this, research on its application to pulp and paper waste problems is incorporated.

* Presented at 1949 Annual Meeting, Pennsylvania Sewage and Industrial Wastes Assn.; State College, Pa.; Aug. 24–26, 1949.

Origin of Process

The high-rate anaerobic digestion process was developed as an outgrowth of a broad experimental program carried on by Buswell and Hatfield (1). This program consisted of laboratory and laboratory-sized pilot plant experiments, in which a wide variety of liquid wastes were digested anaerobically. Although many of these were highly fibrous in nature, or contained much suspended organic matter, some consisted mainly of dissolved organic matter. The discovery that short periods of digestion could reduce the B.O.D. of wastes of the latter character to a high degree led to the development of a digestion process by Buswell and LeBosquet (2) for distillery waste. The short detention periods and apparent high digester loadings obtained with this and similar wastes led to the designation of "high-rate" as applied to this process.

Present Status

High-rate anaerobic digestion is now filling a need for a process capable of handling wastes high in dissolved organic matter, which either cannot be handled by aerobic processes or only at extremely high capital and operating costs. It has been applied to beet sugar, wool scouring, milk, yeast, natural gum, distillery, starch, rice, candy, anti-biotic, and other organic manufacturing wastes. Because a number of wastes produced by pulp and paperboard production appear amenable to such treatment, it is nat-

ural that its effectiveness for purifying these be investigated. Buswell and Sollo (3) studied its application to fiberboard waste. Under fellowship grants from the National Council for Stream Improvement the following projects are underway involving this process:

Waste	Laboratory	Researchers
Strawboard wastes	Purdue Univ.	Bloodgood, Hargleroad, and and Kinnaman
Chipboard concentrate, rag, rope, and jute cooking liquors	Rutgers Univ.	Rudolfs, Nemerow, and Amberg
Semi-chemical pulping liquors	Virginia Poly. Inst.	Vilbrant, Murphy, and Kress
Sulfite waste liquor	Oregon State Univ.	Graf and Ross

Although three of these projects are still in the laboratory or laboratory pilot plant stage, the strawboard project is now in large-scale development at The Terra Haute Paper Company's plant at Terra Haute, Ind. The basic studies behind this development work have been reported by Bloodgood and Hargleroad (4) (5) and Bloodgood and Kinnaman (6).

In order to determine present efficiency levels and evaluate the degree of progress made in recent years in the application of high-rate anaerobic digestion to various trade wastes, it was first necessary to decide on what indices of performance constitute the best criterion of efficiency. Because the use of the process is primarily to reduce the B.O.D. of the wastes and volatile matter determinations are so subject to error and hard to interpret as to their effect on a receiving stream, it was decided that the B.O.D. alone should be used as the basic determinant. Unfortunately, in much of the past work volatile matter has been most frequently used as the basic index of digester loadings, gas production, and purification. This is believed to be a poor method of measurement, as some of the substances entering into the process are volatile, and volatile acids are produced by it. These are lost on drying in the solids determination. Another important error occurring is the loss of CO_2 from carbonates and bicarbonates on ashing, which is reported as volatile matter. This loss can be compensated by ammonium carbonate treatment of the ash. However, it is doubtful if this procedure was employed in any of the reported work.

Necessary Information

The wide use of volatile matter as an index of process performance has made comparison of results obtained with various wastes on the B.O.D. basis difficult, as in many instances necessary data were lacking; in others, considerable recalculations were required. From examination of all available data, together with experience with the process, the conclusion has been reached that the following information is required for evaluation and comparison of high-rate anaerobic digestion studies and practice, as well as control of the process itself.

1. Analysis of the waste, including total solids, volatile solids (ammonium carbonate modification), total suspended solids, volatile suspended solids, pH, acidity, alkalinity, sulfates, nitrogen, phosphorus, 5-day B.O.D., sugars, solvents (if present), and toxic substances (if present).
2. A knowledge of the range of B.O.D. variation in normal waste flow.
3. Average B.O.D. (5-day) value of the waste feed.
4. Average B.O.D. (5-day) value of the effluent.
5. Digester loadings in terms of pounds of B.O.D. (5-day) per day per cu. ft. of digester capacity.
6. Displacement detention time in digester.

7. Gas production per pound of B.O.D. (5-day) destroyed.
8. Temperature of digester.
9. Nutrient addition in terms of elemental phosphorous and nitrogen.
10. Degree of agitation provided, if any.
11. Suspended solids content of digester in terms of percentage in total digester liquor.
12. Volume and consistency of sludge removed from digester, if any.
13. Ash content of digester sludge.

In addition, the volatile acid content of the digester liquor is useful both for control and interpretive purposes. Because the B.O.D. determination requires 5 days for completion, it is suggested that the ratio between the B.O.D. and O.C. values for each raw waste be established, so that the latter may be employed as a working index of digester loading.

It is believed that progress would be accelerated if all experimental work were reported in accordance with the above outline in the future, as direct comparisons of all studies could be readily made.

Experimental Results

In order to determine the state of the art, 10 wastes for which recent and reliable experimental data exist were selected and performance figures tabulated. In Table I, digestion performances obtained for 4 pulp and paperboard wastes are compared with those of 6 others. The compressed yeast waste figures were obtained from pilot plant research conducted by Rudolfs and Trubnick (7)(8), and those for natural gum processing wastes from laboratory studies conducted by Logan and Rudolfs (9). Pilot plant tests by Singleton (10) provided the data on wool scouring waste. The distillery and milk waste figures were obtained from reports of both plant and laboratory investigations of Buswell *et al.* (1)(2), and the penicillin waste work from laboratory studies conducted by Heukelekian (11). The pulp and paperboard information was assembled from laboratory studies by Buswell and Sollo (3) and progress reports of the National Council for Stream Improvement previously referred to, as well as some as yet unpublished reports. Strawboard waste data represent large pilot plant results; chipboard figures, continuous laboratory tests. The semi-chemical pulping liquor data were derived from laboratory-size pilot plant investigations. Because experience has shown that results of properly conducted laboratory experiments can be duplicated in full-scale operation, it is be-

TABLE I.—High-Rate Anaerobic Digestion Performance for Various Wastes

Type of Waste	Dig. Loading (lb. B.O.D./ cu. ft./ day)	Det. Time (days)	B.O.D. (5-Day)			Gas (cu. ft./ lb. B.O.D. red.)	Temp. (°C.)	pH	Nutrients	Agitation
			Feed (p.p.m.)	Effl. (p.p.m.)	Red. (%)					
Settled strawboard conc.	0.06+	3.1	1,833	200	89.1	8.0	32	7.2	No	Yes
Chipboard conc.	0.034	5.0	2,180	509	76.6	8.0	30	7.0	Yes	No
Fiberboard conc.	0.040	5.0	5,350	810	84.9	—	30	—	Yes	No
Semi-chemical pulping	0.025	10.0	3,020	430	85.8	—	30	7.5	Yes	Yes
Wool scouring	0.022	20.0	8,600	1,010	88.2	—	35	—	No	Yes
Compressed yeast	0.100	2.0	4,000	400	90.0	7.5	30	7.0	No	Yes
Natural gum	0.030	5.0	2,100	122	91.5	—	20	7.0	No	No
Milk (whey)	0.020	—	32,000	2,425	92.4	—	28	—	No	No
Distillery	0.070	—	15,500	1,750	88.7	—	56	—	No	No
Penicillin	0.038	20.0	6,680	1,270	81.0	—	20	8.0	No	No

lieved that such figures are comparable.

Loadings and Detention Periods

Examination of the digestion data reveals that high B.O.D. reductions were attained by digestion of all wastes. The loadings and detention periods required varied considerably. Loading rates fell into two general classes—those approaching 0.04 lb. B.O.D. applied daily, and those approaching 0.10 lb. In the former group, chipboard, fiberboard, wool scouring, and penicillin wastes are close to the 0.04-lb. loading level. The natural gum processing waste experiments were conducted at a lower temperature, which probably accounts for the lower loading limit. Experimental work has not yet established a limit for semi-chemical waste liquor. Due to operating difficulties, a limit could not be firmly established for the wool scouring wastes (10). The milk waste studies were conducted when relatively little was known about the process, so that the loading limit was probably not reached. In all probability these wastes could be handled at loadings of at least 0.04 lb. at 30° to 35° C. This level appears to be the present mesophylic limit for most wastes when agitation is not provided in the digester. Evidence of the existence of this limit, in addition to that presented here, was detected throughout pursuance of the literature.

Loadings appreciably above this level are noted for settled strawboard waste, compressed yeast waste, and distillery waste. Evidence is at hand which proves that agitation is responsible for the high loadings obtained for the yeast and strawboard wastes, while the thermophylic temperature employed accounts for the high distillery waste figure. Considerable observations are reported which established a loading limit in the neighborhood of the 0.1 lb. for yeast waste. A maximum has not yet been attained in the strawboard studies, but the same limit probably applies to strawboard as well. It can be concluded, therefore, that, for most wastes of the type amenable to this treatment, digester loadings of 0.04 lb. of B.O.D. per cu. ft. per day can be obtained, with resultant high B.O.D. reductions and stable operations. In the case of some wastes, the loading can be increased to about 0.1 lb. by means of thermophylic temperatures or agitation. These devices do not result in increased efficiency with all wastes. An example is the chipboard waste, for which poorer results were obtained both with agitation and thermophylic digestion. Buswell (1) reports unsatisfactory results for thermophylic digestion of a number of wastes. The character of the solids may have much to do with this, as wastes relatively free of suspended matter appear to respond best to agitation and higher temperature digestion.

The data on detention time and initial strength of influent waste in terms of the 5-day B.O.D. yield some interesting relationships. Most of the wastes, for which 0.04-lb. B.O.D. loadings sufficed, required a 5-day detention period. As indicated in Table II, these had initial B.O.D. concentrations ranging between 2,000 and 5,000 p.p.m. The two exceptions—penicillin (B.O.D. approx. 7,000 p.p.m.) and wool scouring (B.O.D. approx. 9,000 p.p.m.) wastes—required 20-day detention periods.

TABLE II.—Comparison of Loading, Detention Time, and Initial Strength of Wastes

Type of Waste	Loading (lb. B.O.D./ cu. ft./day)	Det. Time (days)	Raw Waste B.O.D. (p.p.m.)
Strawboard	0.10	2	2,000
Yeast	0.10	2	4,000
Chipboard	0.04	5	2,000
Fiberboard	0.04	5	5,000
Natural gum	0.04	5	2,000
Penicillin	0.04	20	7,000
Wool scouring	0.04	20	9,000

The wastes for which 0.10-lb. loadings are possible appear to require only 2-day detention. The strength of these wastes (strawboard and yeast) was in the same range as the lower loading limit group.

Strength of Wastes

The two wastes requiring 20-day detention periods were both strong ones. This is indicative of the existence of a time-concentration function. There is little doubt that such a function exists, but it is doubtful if it explains entirely differences in results with wastes of varying concentration. The character of the organic matter decomposed, and the presence of extraneous substances, which may have a mild inhibiting effect on digestion, are probably also involved.

Another factor that can be of paramount importance to the detention requirement is the suspended solids content of the digester liquor. Too little attention has been given this factor, and for most wastes little data are available from which comparisons can be made. As the sludge present in the digester carries the organisms responsible for the digestion, and the process essentially consists of providing close contact of the waste with the active sludge, it is reasonable to assume that, at least up to a certain limit, the more sludge solids present in the digester the greater the activity. This has been proven the case with activated sludge and there is no reason to believe that the quantity of seed material should not likewise be important to digestion. Undoubtedly, sludges vary to some degree in active organism content and effectiveness; however, to obtain information regarding those variations, comparable concentration data must be made available.

Gas Production

Gas production information that could be calculated on the B.O.D. basis showed that about 8 cu. ft. of gas is produced per pound of B.O.D. destroyed, irrespective of the waste treated. As the gas produced from practically all such fermentations contains relatively the same percentage of methane, these figures are equivalent on the heat value basis.

Unless adjusted artificially, results all show that a stable digestion takes place in a pH range of from 7.0 to 7.5.

Nutrients Needed

Nutrients must be added to any type of waste deficient in nitrogen and phosphorous. For these additions, anhydrous ammonia and super-phosphates of the type used as fertilizer are both satisfactory and the most economical. Nutrients were required for all the pulp and paperboard wastes, with the exception of strawboard waste. Requirements for anaerobic decomposition are considerably lower than those for aerobic oxidation.

Mechanical Requirements

Mechanical requirements for carrying on the high-rate anaerobic digestion process are well understood and in recent years conventional systems have been improved and new methods have also been devised and are under test. Early systems consisted of tall conventional digesters equipped with peripheral weirs at the surface to take off the supernatant. Two-stage digestion was generally employed, because it facilitated control. As the necessity for good raw waste distribution was understood, digesters were equipped with manifolds and nozzles to distribute the influent at the bottom of the tank. A system devised by Gehm and Morgan (12) provides for external sludge-liquor separation and a completely agitated digester. It has the obvious advantages of lower volume requirements and easier control. Whether higher loadings can be obtained than with conventional equipment remains to be seen. A pilot unit

of this type designed for strawboard waste studies has been described (12).

It is understood that Rudolfs and Trubnick have suggested a two-stage system in which the flow can be reversed. This gives promise of improvement over the conventional two-stage system.

Conclusions

It appears from the above discussion that both process- and equipment-wise we are approaching the immediate limit of efficiency obtainable for high-rate anaerobic digestion of trade wastes. Unless higher levels of efficiency can be reached, this process will have quite limited application. The limiting factor inherent to the process, as pointed out by Schlenz and Buswell (13) (14), is that at excessive loadings volatile acids accumulate and gas production fails to keep step. On continued overload, volatile acid formation is also inhibited. The latter is to be expected, as it is well-known that high concentrations of the end product of a particular fermentation will inhibit the organisms responsible for it. It is the general belief that the acid accumulation is also responsible for the diminution of activity of the organisms responsible for methane production. Although this may be true, there is some evidence to show that the character of the gas is altered on overload before changes in other indices of operation, including high volatile acid accumulation, are evident. This may be only a more sensitive indication of the effect of the volatile acids on the methane organisms, or may indicate that another end product of the acid forming organisms appears at high metabolic levels, and is responsible for the inhibition of the gas formers.

One must conclude, in considering the above observations, that if further progress is to be made in developing the high-rate anaerobic digestion process, it must come from the laboratory. The end of the road is being rapidly reached on testing this process for various wastes. It is proving applicable to some and not to others, mainly because of general limited efficiency. Until more is known of the mechanism of the process, particularly under conditions of very high load, further progress cannot be anticipated. The work of Buswell, Barker, and Heukelekian in this direction is to be commended and should be extended in the future at the possible expense of further testing work.

Although little new has been presented in this paper, liberal interpretations of data have been made, and speculative reasoning resorted to at times, it is hoped that it will serve its purpose—that of an appraisal of a most important industrial waste treatment development.

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COAL WASHERY WASTE STUDY

The State Water Commission has started a comprehensive survey of the coal washery waste problem in West Virginia. This survey is the first in a series of specific industrial waste surveys contemplated by the Commission.

There are approximately 175 coal preparation plants in West Virginia. Of that number, less than 10 per cent have approved waste treatment. The greater percentage of these washeries are located in the southern field.

Waste from a coal washery is usually in the form of fine coal, slag, and clay, which appears in the stream as black or grey suspended solids or turbidity and tends to form a black sludge bed on the bottom of the stream. These wastes impair recreational facilities, damage sand and gravel, increase the cost of water treatment for public consumption, deposit on bottom land during periods of high flow, fill up the deep pools where fish usually live, blanket spawning beds and, in general, impart an unwholesome and unattractive black coloring to the streams.

From the study the Water Commission anticipates developing and publishing a coal washery waste manual, which will serve as a guide to the industry in planning waste treatment facilities.

Funds for the study have been made available to the state as a grant from the Federal government through Public Health Service, under the provisions of Public Law 845, the Federal Water Pollution Control Act of 1948.

MILK WASTE TREATMENT BY AERATION *

By Frank J. McKee

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Disposal of waste from dairy plants has become an important problem because of the increased interest of the public in stream pollution and because of the increasing size of many dairy plants. Crossroads cheese factories and creameries are becoming fewer in number. Large milk processing plants, which may handle several hundred thousand pounds of milk daily and are equipped to manufacture a variety of products, are becoming more common. Forces behind this movement are the same that have led to centralization of other industries; namely, it has been found more efficient to operate a few large plants than many small ones. Although this tendency cannot be carried out as completely in the dairy industry as in others, there is a definite trend in that direction. Concentration of operations has produced a corresponding concentration of dairy processing wastes, which may require attention to prevent overloading of existing waste treatment plants and resultant stream pollution.

Wastes result from every process in the dairy plant that involves the handling of milk. The high standards of cleanliness that are maintained make it impossible to use any milk which has been contaminated in any way. This makes it imperative to prevent loss, rather than to recover loss as can be done in some industries. The dairy industry, including equipment manufacturers, has been continually improving its equipment to reduce the loss of milk to a minimum. Modern milk handling equipment can now be provided with automatic controls to prevent the loss of milk due to improper operation. The use of modern equipment, together with the training of operators in its proper use with emphasis on the importance of waste prevention, can result in a substantial reduction in milk solids loss.

It is profitable for the dairy plant operator to spend his money for improved milk handling equipment, such as modern can washers equipped with drip collectors, airtight separators which prevent the loss of foam, closed whey piping systems on cheese vats, and automatic level controllers for tanks. These are outstanding examples of new equipment and installations which increase the product yield for the plant operator and reduce his waste treatment problem. The program of waste saving is important not only in reducing stream pollution, but also in conserving a vital food product. It is the opinion of those concerned with dairy waste treatment that every plant should be given an opportunity to conduct a waste saving program in its plant and to obtain modern equipment designed to reduce milk loss before being required to construct a waste treatment plant.

Experimental Plants

During the past two years, several waste treatment plants using aeration for purification have been built. Two experimental plants were first constructed to determine on a full scale the effects of aeration. These plants

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consisted of a grease trap, pump sump, a cylindrical 8,700-gal. steel tank, and an outlet weir box. Piping was so arranged that the waste passed through the grease trap and entered the pump sump (Figure 1), and then was pumped into the above-ground cylindrical steel tank, in which compressed air nozzles were installed to provide aeration of the waste. The nozzles were installed off center at the bottom of the tank to produce a rolling motion of the liquid.

Compressed air was supplied by means of a 51-c.f.m. rotary blower. Blower and pump operated continuously 24 hr. per day. The overflow from the tank discharged through a float valve, which returned water to the pump sump and allowed only the excess water to pass to the outlet weir.

The plants were designed to provide a minimum degree of treatment, and were built with the intention of using them as experimental plants to determine the feasibility of aeration as a means of treatment. Numerous tests have been made at these plants. Representative results for a 4-day operating period are shown in Table I (Plant A) for a plant producing Cheddar cheese. The whey was trucked away from the plant. The aeration process produced a light sludge, which was usually white in color, but sometimes developed an orange or red tinge. It was apparent that the plants were insufficient in size and blower capacity to provide a completely stabilized effluent. However, they did indicate that

FIGURE 1.—Milk waste treatment facilities at Plant A, showing grease trap, pump house, and aeration tank.

TABLE I.—Representative Operation of Experimental Milk Waste Aeration Plants

	Plant A	Plant B	Plant C
Milk intake (lb./day)	58,200	153,000	71,300
Waste volume (g.p.d.)	7,600	15,960	16,500[1]
Settling of waste	No	Yes	Yes
Recirculation of waste	Yes	Yes	No
5-day B.O.D. (lb./day):			
Influent	125	260	168
Effluent	78	81	59
Reduction (%)	37.0	69.0	65.0
Aeration tanks:			
Volume (gal.)	8,780	16,800	22,220
Theor. ret. time (hr.)	28.5	25.3	32.3
Air supplied (c.f.m.)	51	70	70
Vol. of air (cu. ft.)[2]	588	387	600
O_2 supplied (lb./day)	1,190	1,618	1,618
20-day B.O.D. red. (lb.)	69.0	263.0	160.0
O_2 util. eff. (%)	5.8	16.3	9.9

[1] Includes considerable storm water.
[2] Per pound of 5-day B.O.D. in influent.

the aeration type of treatment had some merit and was worthy of further investigation. The plants were designed so that additions could be made to improve the efficiency of operation.

The next step in experimenting with aeration as a means of waste treatment was the construction of an addition to an existing waste treatment plant. The original plant consisted of two large underground tanks, which served as septic tanks. Although these septic tanks had once provided a satisfactory treatment for the waste, the cheese factory had increased in size to the point where the septic tanks were completely inadequate. New construction involved the installation of two cylindrical steel tanks set vertically above ground. The first septic tank became a pump sump. Three jet nozzles were installed in each of the two steel tanks, and waste from the pump sump was pumped through the nozzles, where it was mixed with compressed air and passed into the aeration tanks. Two 75-g.p.m. pumps and two 70-c.f.m. rotary blowers were installed for operation and standby service. The waste overflowed from the tops of the two steel tanks, which were operated in parallel, and approximately 25 per cent of the waste was passed to a small hopper-bottom settling tank. The remaining 75 per cent

of the waste was returned to the pump suction. The waste discharge to the hopper-bottom settling tank passed over an outfall weir to the stream. The sludge from the settling tank was pumped by means of two air lifts to the second large septic tank, which now serves as a digester. Surveys of this plant have indicated a B.O.D. reduction of approximately 70 per cent. Average operating results for an 8-day period are shown in Table I (Plant B). This plant made Cheddar cheese and condensed whey in a double-effect evaporator.

The next plant also utilized two existing septic tanks, which were employed as settling tanks before and after two cylindrical steel aeration tanks. Air was supplied to the waste through plastic thread wound diffusers mounted at the bottom of each of the aeration tanks. The two blowers had a capacity of 70 c.f.m. each. The pump from the first septic tank to the aeration tanks was operated by a float switch. There was no means of recirculating the waste in this plant. The first aeration tank did not develop any sludge; apparently the anaerobic condition of the waste did not permit such growth. A sludge did develop in the second aeration tank, which also produced a thick "head" of foam. Although this was annoying, it did not interfere with the operation of the tank. Passage of the waste through the first septic tank reduced the 5-day B.O.D. by 15 per cent. The aeration tanks brought the reduction up to 70 per cent. The final septic tank lost 5 per cent, but removed 85 per cent of the suspended solids. Average results of a 6-day operating period are shown in Table I (Plant C). Cheddar cheese was produced at this factory, the whey being returned to patrons.

Plant A shows the least efficient apparent utilization of oxygen. However, as no settling of the sludge was provided, the reduction was all due to oxidation of the organic solids. Plants B and C were both provided with septic tanks for settling, in which the sludge formed in the aeration tank was removed from the effluent, thus increasing the efficiency of the process but leaving the operator with a sludge handling problem. It apparently is not practical to attempt to oxidize completely the sludge formed in the aeration process. The most aggravating operating problem has been the handling of the sludge. Trucking out the liquid sludge and dumping it in locations where it will not cause nuisance appears at present to be the most practical solution.

The increased apparent utilization of oxygen in Plant C, as compared with Plant B, may be due to the difference in the methods of air diffusion and to the recirculation of the aerated waste to seed the incoming waste in the case of Plant B.

Application of Test Results

A completely new aeration plant employing many of the same principles incorporated in the previously described plants was completed recently. This plant includes two aeration tanks and a hopper-bottom settling tank, operated in series, and a hopper-bottom digestion tank (Figure 2). Waste from the cheese factory passes over a weir to the pump sump and is pumped into the first aeration tank. It then flows by gravity through two aeration tanks and the settling tank. An air lift is installed to remove sludge

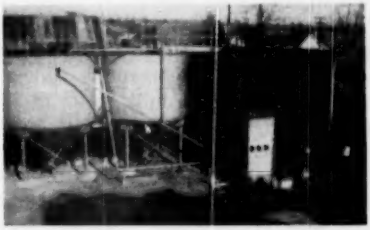

FIGURE 2.—Recently completed milk waste treatment plant utilizing principles established in plant-scale tests.

from the settling tank and discharge it either to the digester or to the pump sump. The overflow from the settling tank passes over a weir and to the outfall sewer. No composite samples have been taken at this plant, but some single samples have shown excellent B.O.D. reductions.

The plants described have demonstrated that the aeration process for treating milk waste can be operated even though the strength of these wastes may be as high as 2,500 p.p.m. 5-day B.O.D., and that efficiencies up to 70 per cent reduction in B.O.D. are possible. The latest plant of this group now in operation should be considerably more efficient than the others, as a settling tank and separate sludge digestion has been substituted for a septic tank as the final stage of the treatment.

The most important point to be considered in regard to these aeration type treatment plants is that they are comparatively low in cost in relation to waste treatment plants of the trickling filter type. It is estimated that an aeration-type plant can be built for approximately one-half of the cost of a trickling filter plant. In areas where power costs are reasonable, the operating cost of these plants is not excessive.

Because privately owned industrial plants must pay taxes as well as interest on the capital invested in waste treatment plants, it is to their advantage to keep that investment as low as possible. On the other hand, municipally owned plants, which are not subject to property taxes, may justify a much larger investment in order to obtain some additional operating economies.

It is hoped that the experiences with these plants may be of benefit to others in the solution of their waste treatment problems.

Acknowledgment

Grateful acknowledgment is made of the use of field data collected by the staff of the National Dairy Research Laboratory.

DISCUSSION

By S. Leary Jones

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It is unfortunate that the selection of dairy plant sites is not the responsibility of technical personnel such as Mr. McKee instead of the vice-president in charge of locating new plants. Proper selection of the plant site, good housekeeping, and adequate treatment works are three important considerations associated with milk waste treatment. Three new dairy plants were recently located in Tennessee with absolutely no consideration of the industrial waste problem, which should have been anticipated. Two of these plants still have not obtained adequate water supplies. Both the water supply and industrial waste problem could have been prevented by a better selection of sites in the same areas and on the same highways.

Mr. McKee comments on the concentration of operations, which has produced a corresponding concentration of industrial wastes. This need not cause stream pollution if the same careful attention is given to solving the industrial waste problem that is given to solving the production problem. It can and has been serious when the concentration occurs in a small town and the industrial wastes are discharged into the municipal

sewer without adequate pretreatment. This is especially true when the municipality does not expand its treatment works to treat the increased load.

For example, in a town with a connected domestic population of 1,000, whose treatment plant also received a milk waste load from one plant equivalent to 4,000 persons, based on B.O.D., treatment is provided in an Imhoff tank and the receiving stream flow frequently drops to 1.0 c.f.s. A new petition is received each time the stream becomes septic. A similar situation has occurred in a city having a connected sewage population of 10,000, a sewage treatment plant designed for a population equivalent of 12,000, and an industrial waste load —primarily milk wastes—equivalent to about 20,000 persons. The expected condition occurred in the receiving stream and another petition was received.

Both the city and the milk industries are at fault in these and other similar cases. The city has tried to give or sell sewerage services that it does not have available to furnish, and the milk industries should have been aware of the situation that they would create. At least pretreatment would have been in order prior to the discharge into the city sewer. All industries that discharge wastes into a city sewer should provide a method for measuring and sampling their wastes. This will prevent considerable headaches for both the industry and the city when it is necessary to determine the load on the sewerage system.

Mr. McKee has stressed waste saving. This is quite important, but often neglected in the dairy plant. One plant recently examined was losing about 7 per cent of the milk processed, based on the pounds of B.O.D. in the effluent. This occurred during the winter when the cans of milk received at the plant contained a ring of milk-ice, which was carried into the can washer. Other plants have been losing up to 5 per cent of the milk because of extremely careless operation. Well-operated plants that keep the losses to a minimum also are found, of course.

Another incident is worthy of mention. The plant manager removed the the clear cooling water from the city sewer and found that the cooling water appeared to contain as much milk as the plant sewer. It seemed that there was a leak in one of the cooler shells. The manager still turns pale when it is suggested that the leak may have been there for years. Correction of this leak reduced the milk lost to the sewer about 30 per cent.

State engineers recently examined a milk receiving station that had installed a recirculating trickling filter plant. Although the efficiency of treatment was about 92 per cent, the effluent still contained over 500 p.p.m. of 5-day B.O.D. because the untreated waste had a 5-day B.O.D. of about 5,700 p.p.m. The plant did not have drip savers or a can washer. Although milk losses were excessive, this plant is mentioned to stress one point in particular. Efficiency of treatment reported on a percentage does not tell the entire story. The receiving stream is interested only in the pounds of pollution in relation to the quantity of dilution water available in the stream.

Whey is always a problem at cheese plants unless adequate provisions are made in the design of the milk plant. Within the past four months the whey tanks at three separate cheese plants have been seen overflowing to the sewer. Some managers frankly admit that all of the whey is discharged to the sewer.

The Tennessee Stream Pollution Control Board has encouraged recovery and waste saving, giving them equal credit with treatment. The standard recommendation, in most cases, is that adequate recovery or treatment works be provided. The re-

covery method, of course, should be reasonably foolproof.

Treatment by aeration has considerable merit and this development is being followed with considerable interest. As Mr. McKee mentioned, one plant of this type is located in Tennessee and plans recently were approved for a second installation.

It is desirable and necessary for industry to experiment to find better methods for treating wastes. Companies that do not have staff personnel to design adequate treatment works need the services of consulting engineers. A sad situation recently arose at a new milk plant that built a trickling filter to treat its wastes, without the benefit of technical advice. Loadings on the so-called standard-rate filter were found to be 18,000 lb. of 5-day B.O.D. per acre-ft. per day. The existence of the plant was unknown until after the milk plant was completed and placed in operation.

I wish that Mr. McKee had mentioned the work being done by the Dairy Task Committee, which has outlined a program that it is hoped will produce results.

CORRECTIONS—1949 INDUSTRIAL WASTES FORUM

In the "Forum on Industrial Waste Problems" (THIS JOURNAL, June, 1950), two errors in the transcript have been noted. On page 779, under the heading "Discussion," Prof. Bloodgood's question should read, "Do you allow the operation of lagoons for canning waste in New York State *without* the addition of nitrate?"

Also, on page 787, Mr. Gurnham's discussion should read. "It is a well-known fact, chemically, that sodium *sulfide* has a chlorine demand, and so has sulfite."

AUTOMATIC WASTES SAMPLER*

By S. C. Gray, R. J. Trost, and D. V. Moses

E. I. du Pont de Nemours Co., Belle, W. Va.

In the river pollution abatement program of the du Pont Company, it was early recognized that collection of representative samples of sewer effluents was of prime importance. As experience showed that the manual collection and compositing of hourly samples was both laborious and unsatisfactory, efforts were turned toward automatic collection of a representative sample.

Sewer conditions at the Belle plant impose severe service conditions on such a sampler, primarily because of the required 18-ft. suction lift, but also because of high channel velocities and suspended air. The struggles to evolve a serviceable sampler, extending over a period of about 10 years, will not be detailed here; it is sufficient simply to state that a wide variety of pumps and flow splitters were tried. The form of intermittent, short-cycle sampler finally developed is satisfactory for the use intended, and a number of them have been in service for more than a year.

The arrangement of the sampler is shown in Figure 1. In this unit, a flow of about 5 g.p.m. is drawn continuously by a jet pump, of the shallow well type, through the inlet pipe, which faces downstream to avoid inclusion of sand or other suspended matter. The discharge of the jet pump passes through an elevated vented overflow pipe to waste. A solenoid valve, controlled by a timer and installed in a side connection below the overflow, intermittently opens to allow the quantity desired for sampling to enter a stainless steel drum, where it is periodically mixed and

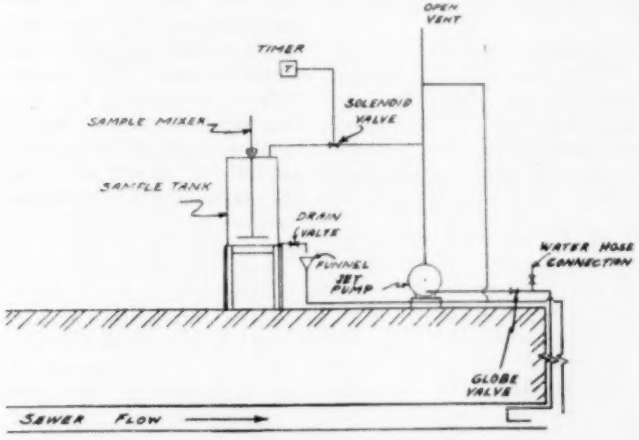

FIGURE 1.

* Presented at 1949 Annual Meeting, West Virginia Sewage and Industrial Wastes Assn.; Wheeling, W. Va.; Sept. 20–22, 1949.

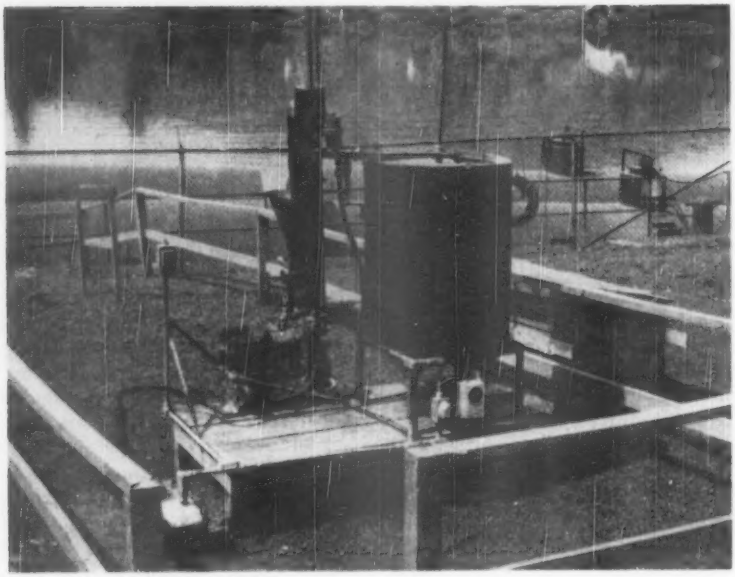

FIGURE 2.

sampled. In the device, which has an overflow pipe giving a 2-ft. head on the valve, a 10-sec. sample drawn at 2-min. intervals approximately fills the 55-gal. drum in 24 hr. The laboratory sample is drawn while the drum is draining. A view of one of the sampler installations is shown in Figure 2.

A more elaborate alternate type of sampler, which will collect a sample proportionate to the sewer flow, requires the substitution for the timer of a standard integrating flow recorder equipped with electrical contacts and a timing relay. The recorder may be used with a Kennison nozzle, Parshall flume, or other flow-measuring device at the sewer outlet. Contact is made by the recorder after passage of a predetermined volume and the relay maintains the contact for the required period, allowing the sample to flow into the container. As the flow in these particular sewers is substantially constant, and as most of the outfalls are submerged so that measurement is difficult, no occasion has arisen to use this alternate device. Its practicability is a reasonable certainty, however, because of experience with similar equipment in water treatment.

FEDERAL INDUSTRIAL POLLUTION STUDIES *

By Hayse H. Black

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Industrial wastes and water pollution problems resulting therefrom constitute a major phase of the Federal program for water pollution study and control. In discussing this subject, it should be noted at the outset that it is not intended to do industry's job, but rather to supplement the research being conducted by industry. This paper briefly describes industrial waste pollution abatement trends, outlines the current approach to the problem, and indicates the response of industry.

Pollution Abatement Trends

The American public is aware of the benefits which accrue to abatement of water pollution. This knowledge has come firsthand to millions who have been compelled, at times, to drink unpalatable water. Absence of normal aquatic life in streams draining densely populated, highly industrialized areas has provided further visible evidence of damage to a common heritage.

Since adoption of the water carriage sewage system, early in the 19th century, pollution of surface waters has increased steadily. Degradation of natural waters by polluting substances, in the form of industrial wastes and domestic sewage, has directed public attention to the dire need for comprehensive corrective measures for restoration and protection of our streams, lakes, and coastal waters.

Substantial progress was made in sewage treatment during the 1930's. Public works projects during and following the depression served as a stimulus, especially in construction of much-needed municipal sewage treatment works. This era of advancement in sanitation was disrupted by war scarcity of building materials and high construction costs. The pendulum has now swung back and we are currently engaged in a nation-wide drive to curb water pollution.

Enactment in 1948 of Public Law 845, officially designated the "Water Pollution Control Act," has placed new emphasis on the industrial pollution problem (1). This law recognizes the primary responsibilities of the states in controlling pollution, and offers, for the first time in the nation's history, a broad coordinated program of water pollution control.

Concurrently with drafting and enactment of Federal water pollution control legislation, several states have passed new laws and others have strengthened existing statutes for control of water pollution. Recent formation of the Ohio River Valley Water Sanitation Commission is another manifestation of the public demand to abate pollution.

Industry has joined forces with stream control agencies in this gigantic task. It has been estimated that U. S. industries will invest more than $3,000,000,000 during the next decade in reducing water and air pollution (2). The consummation of such plans would be a powerful answer to the allegation that industry is dragging its feet in this program.

* Presented at 48th Annual Convention, National Lime Assn.; Hot Springs, Va.; May 12, 1950.

Approach to the Problem

The three basic elements fundamental to correction of industrial waste pollution are:

1. An active coordinated program.
2. Industrial waste research.
3. Application of findings.

Program

Acting in accordance with Public Law 845, the Public Health Service is approaching this problem jointly with state governments by establishing close working relationships with industry, municipalities, interstate agencies, other Federal agencies concerned, and private organizations whose basic programs are related to industrial wastes and water pollution. The recently organized National Technical Task Committee on Industrial Waste provides top level coordination (3).

The Public Health Service, with a large measure of state and local assistance, is currently developing comprehensive programs for 11 major drainage basin areas covering the United States (4). The primary objectives of these comprehensive programs for water pollution control are to:

1. Show existing stream conditions, including pollution load.
2. Determine essential stream uses.
3. Establish water quality criteria for various uses.
4. Develop corrective measures based on the first three.

The primary functions of these reports will be to:

1. Enable a stream to be considered as a unit, unbroken by political boundaries.
2. Provide related programs of pollution control for states using the same stream.
3. When summarized collectively, provide the country with a reasonably accurate picture of the cost of pollution control.
4. Enable industry to learn what is expected of it in the way of cleaning up its share of stream pollution.
5. Secure uniformity from state to state in the degree of pollution abatement required under like circumstances.

Industrial wastes and problems attendant therewith constitute an ever-expanding frontier. When it is realized that industry is applied science and that science possesses no boundaries, the infinite possibilities in the allied field of industrial wastes become immediately apparent. Scientific research and development create the foundation upon which modern industry builds. These same creative forces must continue to solve the new waste problems resulting from industrial expansion.

Commendable research is being conducted by trade associations, professional organizations, institutes, and foundations representing major industries (5). Results of these projects should contribute to the solution of some of the more complex industrial waste problems. A number of corporations have established full-time research units for study of water pollution problems.

The Public Health Service supports and fosters industrial waste research in three ways (6):

1. Environmental Health Center (E. H. C.) activities in connection with laboratory investigations and field studies.
2. Grants to states and interstate agencies for industrial waste studies.
3. National Institutes of Health grants to organizations and individuals for fundamental research.

E. H. C. Laboratory Research

The Environmental Health Center, located at Cincinnati, Ohio, is the technical arm of the Public Health Service in the conduct of research and investigation in the field of environmental

health. The Center laboratory research having direct bearing on industrial waste pollution problems currently includes such projects as:

1. Improvement, modification, and simplification of analytical procedures.
2. Biological and chemical treatment of wastes containing radioactive materials.
3. Study of factors governing the persistence of particular constitutents of industrial wastes in their travel through surface waters.
4. Extraction and identification of organic pollutants present in drinking water taken from surface sources.
5. Development and standardization of bio-assay techniques for determining the toxicity of industrial wastes.

E. H. C. Field Studies

The Environmental Health Center industrial waste field studies are cooperative projects with the states and with industry, being conducted at selected manufacturing plants where the results promise to have national or regional significance. The typical field unit staffs are each composed of two engineers, two chemists, and three scientific aides. These teams operate from mobile laboratories, which are located at the industrial plants being studied. The industrial representative is usually from the research department, but may be from the engineering department. Industry assumes responsibility for installation of flow-measuring equipment when necessary, the collection of representative samples, and utilities for the mobile laboratory. A single project is normally completed in one month, but may extend through three months, depending on the magnitude of the problems. The technically trained field crews, collaborating with the industrial research departments, have contributed much to mutual understanding of industrial waste pollution problems.

The field studies are as diversified as industry itself. Efficiency of by-product recovery is frequently determined. Evaluation of new waste treatment processes by pilot plant operation, or performance tests on full-scale equipment, are typical special studies. A solids or chemical constituent balance may be determined when significant. It is often possible to explain major variations in the characteristics of combined wastes from a plant by well-organized surveys. The potentialities of combining industrial wastes with domestic sewage for treatment are almost unlimited. Concerted effort is being made to correlate industrial effluents studied with existing conditions in the receiving stream.

During the 1949 beet sugar season, a considerable amount of experimental work was done with these wastes, especially the pulp water and pulp press liquor. Lime treatment of the pulp water and press liquor in a pilot plant, using a dose of 500 p.p.m. CaO and 2-hr. theoretical retention, gave 90 per cent removal of suspended solids and 25 per cent B.O.D. reduction. Highly preliminary bacteriological studies revealed effective destruction of thermophiles by lime treatment of this process water, suggesting possible further treatment by carbonation and its return to diffusion battery water make-up. Sludge from lime treatment was a greenish-tan, viscous liquid ranging from 2.8 to 6.6 per cent solids concentration, and averaging 5.5 per cent.

Another phase of the current field program is the detailed study of wastes from integrated steel mills, with emphasis being placed on by-product coke operations. Each project contributes additional valuable information and suggests opportunities for further productive work, all directed toward permanent pollution abatement. Emphasis is placed on coordination and full utilization of the professional services of Environmental Health Center engineers, chemists, and

biologists. Data and information obtained from field studies, technical literature reviews, and research will serve as the basis for the preparation of "Industrial Waste Guides" for each major industrial waste.

W. P. C. Grants

The Water Pollution Control Act authorizes an appropriation of $1,000,000 per year "to be allotted equitably and be paid to States . . . and to interstate agencies for expenditure by them for the conduct of investigations, research, surveys, and studies related to the prevention and control of water pollution caused by industrial wastes." For the fiscal year ending June 30, 1950, these funds were allocated as follows: states, $850,000; interstate agencies, $60,000; and special industrial waste studies having regional or national significance, $90,000.

Special industrial waste studies currently being conducted under these grants include:

1. Development of methods for treating citrus canning wastes.
2. Determination of the effect of toxic metal-plating wastes on biological sewage treatment.
3. Development of standards for industrial wastes treatment methods.
4. Development of methods for treatment and disposal of wool scouring wastes.
5. Study of the disposal of sugar beet wastes by the lagoon method.
6. Study the effects and tolerance limits of various industrial waste constituents, including pulp and paper mills, on certain types of aquatic life.

N. I. H. Grants

National Institutes of Health grants are confined to fundamental or basic research. This policy eliminates development work, experimental pilot plants, and field surveys. Since May, 1949, funds totaling $113,661 have been authorized, covering 18 projects in the field of sewage and industrial wastes. Other projects are being considered for approval and activation.

In addition to the foregoing, a great many industrial waste research projects are in progress at individual manufacturing plants and in connection with advanced academic work.

Application of Findings

Research, in itself, is simply a scientific means to an end. It is of limited value until applied. The subject of lime use in treatment of industrial wastes has been presented (7). Likewise, the "Symposium on Lime," sponsored by the American Chemical Society in 1927, has provided a background for lime in the chemical industry, emphasizing its merits as a safe, low-cost, readily available alkali (8).

Industrial Response

During recent years, industry has shown a cooperative attitude toward water pollution control. In fact, numerous industries today experience difficulty in obtaining sufficient water of satisfactory quality for process without costly treatment. Such conditions definitely impede industrial expansion and normal growth of a community.

In the past, some process waste problems have been solved through by-product recovery—and at a profit. The distilling industry is an example; high grade stock food is produced from the spent mash. However, all process wastes do not contain valuable ingredients in sufficient concentration to permit economical recovery. In other cases, the job of establishing a market for the new product appears insurmountable.

There is a tendency to carefully scrutinize process, with a view toward raw material change or process modification that would prove advantageous in waste reduction. New processes have been radically changed when the wastes were found to be serious pollutants. The industrial waste problem

is but one phase of industrial development.

New industrial sites should be, and in many instances are being selected with full knowledge of waste treatment requirements consistent with established use of the receiving waters. Sewer design for new plants or expansion of existing facilities provides service for clean water separate from that for concentrated wastes requiring treatment. This obviates the need of costly reconstruction.

Discharge of industrial wastes to municipal sewerage systems is attractive where this is possible without disrupting operation of the treatment works. Fixed charges are minimized and it is possible to formulate surcharge to provide equitably for operation costs. Pretreatment and/or equalizing tanks may be required at the industry.

Separate treatment of industrial wastes is accepted as another process. It may be expensive, and concerted effort is made to hold operation costs to an absolute minimum. When chemicals are employed, preference will be given to the least expensive. Lime should continue to have advantages when an alkali is required.

There is a trend toward maintaining a continuous record of the volume and characteristics of industrial discharges. Continuous records are invaluable in the detection of irregularities (such as "spills"), which are inevitable when operation controls are not fully adequate. Such records afford desirable protection against litigation.

A matter of primary concern to industry is the classification and assignment of quality and purity standards to designated waters. The capacity of natural waters to assimilate industrial wastes of various combinations is of equal interest.

Conclusion

The art and science of industrial waste treatment must keep in step with industrial progress. Current and planned research will contribute much to knowledge in this field. The ultimate solution to the industrial waste problem is to make it a part of industrial development. Cooperation of all concerned will hasten the day when our surface water resources will be satisfactory for their many and varied uses.

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SIMPLIFIED DISSOLVED OXYGEN COMPUTATIONS*

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With the publication in 1925 of "Public Health Bulletin 146" (1), there became available a mathematical approach to the determination of the natural self-purification capacity of a stream, or a stream's capacity to absorb oxygen-depleting pollution. Since that time, other workers have developed refinements and simplified methods for using the oxygen sag formula (2)(3)(4), and in 1949 Streeter (5) published a nomograph for the solution of problems involving the use of this seemingly complex equation. Closely allied to the determination of the natural self-purification capacity of a stream are determinations of the degree of sewage treatment required in a given situation and the effects on oxygen conditions of increases in low stream flows.

Practical use of the mathematical approach has been limited by lack of understanding of the fundamental principles involved and by the seeming complexity of the calculations required. With the continued growth of pollution problems and the stress being placed on control measures, it is becoming increasingly important that the sanitary engineer be acquainted with methods of computing oxygen relationships in streams.

The purpose of this paper is to outline an approximate method for estimating the degree of waste treatment required to maintain a given dissolved oxygen objective in a stream. The method, which uses dissolved oxygen and flow results in the stream itself as base data, is an abbreviation of the Streeter-Phelps procedure with an accuracy which is believed to be comparable to the precision of the base data available in many instances. It can also serve as a means of estimating the benefits to be obtained by reducing the required degree of treatment due to the regulation of low stream flows through the use of storage reservoirs.

The standard method of mathematical analysis of oxygen conditions in a polluted stream is by the use of the oxygen sag formula, which describes the progressive depletion and recovery of dissolved oxygen in the water as it flows downstream. The formula is

$$D_t = \frac{k_1 L_a}{k_2 - k_1} (10^{-k_1 t} - 10^{-k_2 t}) + D_a (10^{-k_2 t}) \quad (1)$$

in which

D_t is the p.p.m. oxygen deficit below saturation after any time, t, in days;

D_a is the p.p.m. initial oxygen deficit below saturation;

L_a is the pollution load, stated in terms of the total first-stage B.O.D. in p.p.m.; and

k_1 and k_2 are the respective velocity constants for deoxygenation and reoxygenation.

In any given situation of stream conditions there is wide variation in the above factors. The velocity constant for reoxygenation, k_2, is subject to wide variation in different streams, in individual stretches of any one stream, and for various river stages in the same stretch. Although variations in k_1

* Summarization of lectures delivered at Sanitary Engineering Training Course, U. S. Public Health Service, Environmental Health Center, Cincinnati, Ohio, 1948 and 1949.

are usually of somewhat lesser magnitude, they too may be appreciable, and in many situations it is quite difficult, if not impossible, to derive acceptable values for these velocity constants. In addition, the pollution load and the initial oxygen deficit may be subject to considerable variation, depending on conditions at a given time. The method of analysis outlined herein permits direct analysis of the oxygen-flow relationship in a given stretch, and avoids the use of factors such as k_1 and k_2.

The method outlined cannot be expected to give better results than the oxygen sag formula itself used without adjustment of k values for variable stream stage. The method gives best results in the study of conditions in large and medium sized streams, where the effect of variations in k_1 and k_2 with river stage may be expected to be relatively minor. In small, rapidly flowing streams, one or several factors, for example k_1 or k_2, may fluctuate greatly, and such variations may introduce inaccuracies when estimates are made under flow conditions greatly different from those at the time of sampling. In situations where the effect due to algae is a dominant factor, an analysis of dissolved oxygen results is difficult either by this method or by the oxygen sag formula. When sludge deposits create a major portion of the oxygen demand in the critical stretch, estimates of the required degree of sewage treatment may be overly conservative when based on the method outlined.

Dissolved Oxygen vs. Flow

By use of observed dissolved oxygen profiles for the stream stretch in question, as determined by stream water sampling and analysis, it is possible to locate the low or critical point on the sag curve. This low point will not always be at the same stream station, but will move up or downstream, depending on temperature, rate of discharge, and other factors. In estimating the required degree of treatment and the effects of flow variations, principal interest is in the worst oxygen conditions at any time, and therefore in the lowest dissolved oxygen on any profile, regardless of location.

The first step in analyzing conditions, by the method herein described, is to plot the observed critical D.O. results against flow records at the nearest available station (Figure 1). To eliminate or to minimize the temperature effect, the D.O. results used for this curve should be only those observed within a relatively small seasonal temperature range (that is, under summer conditions at approximately 20° to 30° C.) Observed critical D.O. results may also be corrected to those for a selected critical temperature, say 25° C., by a procedure outlined later. The data of Figure 1 were corrected to 25° C. before plotting.

Experience has indicated that, if enough observed data are available, the points will be arranged in the form of a hyperbola. Examination of the oxygen sag formula indicates that this is to be expected. This is illustrated as follows:

The total first-stage B.O.D. (in pounds), which may be considered as the constant, C, for the case of a steady pollution load introduced into an otherwise unpolluted stream, is 5.4 L_aQ, in which Q is the stream flow in cu. ft. per sec.
Therefore,

$$L_a = \frac{C}{5.4Q} = \frac{C_1}{Q} \qquad (2)$$

Furthermore, if there be no initial D.O. deficit, and assuming that k_1 and k_2 remain constant within the range of conditions under study, the oxygen sag formula reduces to

$$D_c = L_a C_2 \qquad (3a)$$

or

$$D_c = \frac{C_1}{Q} C_2 = \frac{C_3}{Q} \qquad (3b)$$

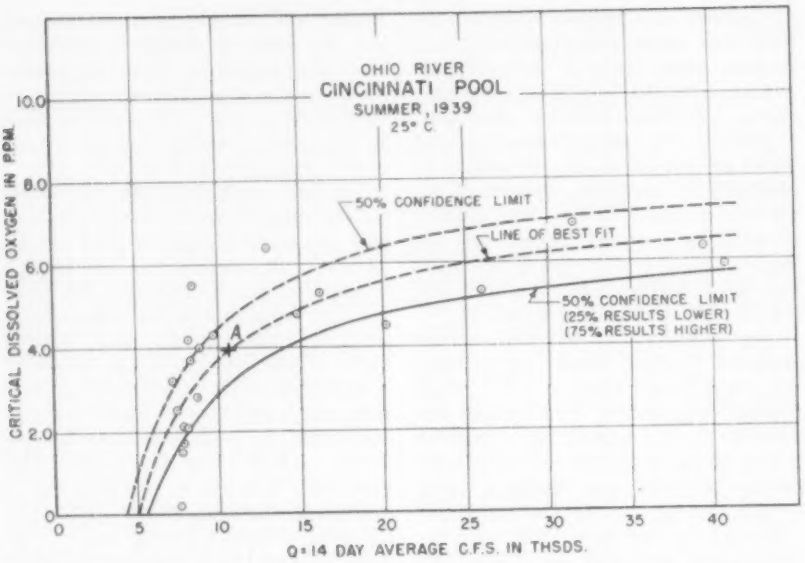

FIGURE 1.—Relation of observed critical D.O. to flow in Cincinnati Pool, Ohio River, during summer of 1939.

from which

$$D_c Q = C_3 \qquad (3c)$$

—a constant.

The proportionality between D_c and L_a at the critical point may also be shown by analysis of the oxygen sag equation (7). The sag curve is defined by the differential equation

$$\frac{dD}{dt} = K_1 L - K_2 D \qquad (4a)$$

Therefore, at the critical point

$$\frac{dD}{dt} = K_1 L - K_2 D_c = 0 \qquad (4b)$$

which reduces to Eq. 3a. Thus,

$$D_c = \frac{K_1}{K_2} L = L_a C_2$$

The hyperbolic function defined by Eq. 3c can be stated in two important ways: Flow (in c.f.s.) times D.O. deficit (in p.p.m.) is constant; or the critical D.O. deficit (in pounds per day) is constant.

Because the curve will be hyperbolic, it will have definite limits; on the x axis it is limited by zero flow, and on the y axis by the level of oxygen saturation at the given temperature. From a study of the plotted data, it is sometimes possible to complete a fairly satisfactory curve by eye, placing greatest weight on the critical or lower oxygen values. When the critical D.O. result is observed to be zero, the result is indeterminate in the same sense that a zero D.O. result in a B.O.D. bottle is indeterminate. It is suggested that critical D.O. levels of zero be eliminated in studying the D.O.-flow relationship.

For convenience, as explained later, Eq. 3c can be written in another way. If S is the D.O. saturation value, in p.p.m., and DO_c is the critical (minimum) D.O., in p.p.m.,

$$D_c = S - DO_c \qquad (5)$$

and Eq. 3c becomes

$$(S - DO_c)Q = C_3 \qquad (6a)$$

or

$$DO_c = -C_3\left(\frac{1}{Q}\right) + S \qquad (6b)$$

A statistical method of constructing the curve can be used. In this method, D.O. is plotted against the reciprocal of the flow ($1/Q$). A straight line results (Figure 2). By using $1/Q$ instead of Q as the abscissa, the straight line which best fits the observed data may be determined by the method of least squares, and a correlation coefficient computed to test the reliability of the relationship. A low level of correlation indicates that true critical data have not been obtained, or that a straight line is not the best possible type of curve for describing the relationship. Some limitations of the method have already been pointed out, and in such situations low correlation might result. In the case of the Cincinnati Pool on the Ohio River, used for purposes of illustration, a correlation coefficient of 0.80 is obtained, and in the Pittsburgh Pool on the Ohio River, a correlation coefficient of 0.90 is obtained. Good correlation has also been found in unpooled, or free-flowing, stretches of other streams.

A near approach to the mathematically fitted curve can be constructed by the following procedure:

The D.O. and reciprocal flow ($1/Q$) values can be averaged and the result plotted (point A, Figures 1 and 2). A straight line can then be drawn through point A on Figure 2 and with a slope such that the line will pass as near as possible through the individual points. Approximately the same number of points usually are below and above the line, which represents average conditions. It will be noted, in the example used, that the line intersects the y axis at a value (7.36 p.p.m.) somewhat less than saturation (8.38 p.p.m.). This value of less than true saturation has been found on a number of streams studied by the Public Health Service in recent years, and may reflect the fact

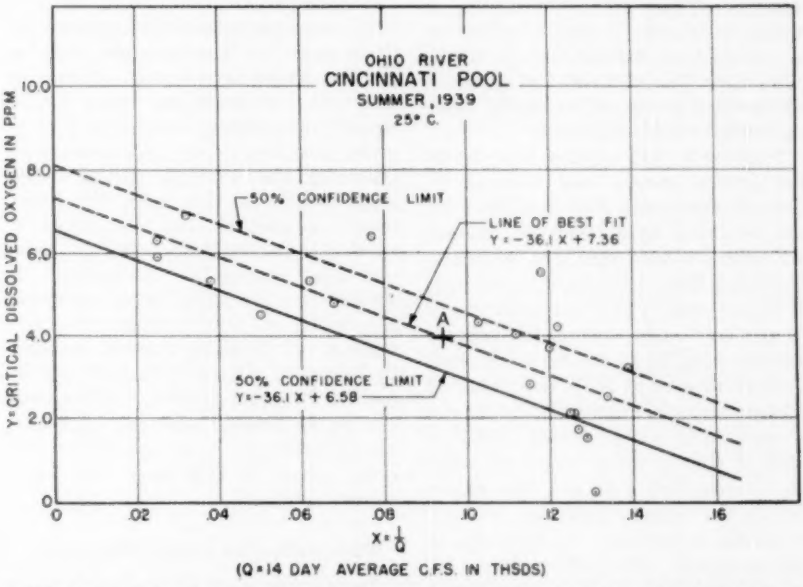

FIGURE 2.—Relation of observed critical D.O. to reciprocal of flow in Cincinnati Pool, Ohio River, during summer of 1939.

that an unpolluted stream is seldom 100 per cent saturated with oxygen.

On the theory that fish are killed not by average conditions but by lower than normal oxygen conditions, the lower of the 50 per cent confidence limit lines is suggested for design purposes. By simplified methods this line is drawn on Figure 2 parallel to the average line and with 25 per cent of the results below the line and 75 per cent of the results above. This design curve is shown as a full line on Figures 1 and 2, and was fitted by the statistical approach.

If the design curve is constructed as suggested, the curve may be said to describe the relation between flow and the critical D.O. for a stream in which k_1 and k_2 may be taken as constants over the range of flows under consideration. Such a curve has a number of uses. For example, to maintain 4.0 p.p.m. D.O. under existing conditions in the case illustrated in Figure 1, a flow of 14,300 c.f.s. is the indicated requirement. However, it should be remembered that primary treatment of sewage is almost always a minimum requirement for desirable stream conditions, from the standpoint of eliminating sludge deposits, objectionable floating sewage solids, and scum.

Treatment will reduce this figure and future growth will increase it. Thus, if the design flow is 6,300 c.f.s. and, as above, 14,300 c.f.s. is required, the pollution load that can be assimilated is 6,300/14,300 of that existing, or 44 per cent. This indicates that a 56 per cent reduction in the organic pollution load by treatment is required. However, if growth in the design period is 26 per cent, the residual load that can be assimilated will be $6{,}300/(14{,}300 \times 1.26)$ of that existing, or 35 per cent. This means that a 65 per cent reduction in the organic pollution load by treatment is required. A summary of this discussion with both a 4.0 p.p.m. objective and a 5.0 p.p.m. objective is as follows:

	(A)		$\left(B = 1 - \frac{6{,}300}{A}\right)$	
	Flow required with no treatment[1] (c.f.s.)		Reduction required in organic pollution (%)[2]	
D.O. objective (p.p.m.)	4.0	5.0	4.0	5.0
Present conditions (from graph)	14,300	23,000	56	73
With 26 per cent growth	18,000	29,000	65	79

[1] Treatment may be required for prevention of sludge deposits, floating sewage solids, and scum, or for bacterial reduction.

[2] With design flow at 6,300 c.f.s.

There is reason to believe that the degrees of treatment required, as estimated, are conservative. For example, if primary or more treatment is provided, the deoxygenating effects of sludge deposits would be reduced. In computing the required degree of treatment, no account is taken of this effect. To offset this factor, in part, installation of intercepting sewers and treatment changes the points of discharge from many to one or, at most, two or three.

An objection might be raised, in that little attention has been devoted to possible initial D.O. deficit, D_a, above the source of pollution. If it is assumed, in applying the method to a given situation, that pollution from upstream sources will be reduced to the same extent as that from the community in question, the necessity for a correction for residual pollution from upstream sources is minimized. A similar situation exists when estimates are made of flow requirements for dilution of partially treated wastes. In this case, all pollution sources will receive the same dilution. The effect will be as though pollution from upstream sources is again reduced to the same extent as that from the community in question.

Flow Period for Design Standards

In any stream, there is some interval between the time when discharge

reaches a minimum condition and the time when D.O. reaches the minimum level—in other words, the D.O. lags behind the discharge by some definite period of time. This lag period may be due to one or more of a number of factors. Time may be required to reach a condition of biological equilibrium following a change in conditions such as the onset of low water. Time may be required for the accumulation of sludge deposits after a period of high flow. In the case of a canalized stream, used as an example, the navigable pool is filled with water of relatively good quality following a period of high flow and time is required to build up the normal concentration of pollution after the onset of low water. Where the absolute minimum flow is of short duration, this "pool" effect tends to mix the pollution with more diluting water than the minimum flow would indicate to be available. In setting minimum stream standards as a basis for sewage treatment plant design, it is necessary to consider this lag interval.

A useful tool in this regard is the daily hydrograph for the entire period of survey, with the observed critical D.O. results superimposed on the hydrograph, each on its proper date of sampling. It is possible by the use of this device to estimate the lag between discharge and D.O., or the approximate number of days by which the D.O. level lags behind the flow. For the case used as an illustration, which is a stretch of pool located behind a dam, it was estimated that this lag amounted to approximately two weeks (Figure 3). In this particular case, therefore, it would be advisable to base stream and design standards on the minimum expected average two-week flow period during the summer. However, in plotting Figures 1 and 2 in such cases, the two-week flow prior to the D.O. plotted should be used, and design flows should be stated as two-week flows.

The lag period will differ for each set of stream conditions, and should be determined individually for each problem and each survey period. On small streams with no pooling effect, D.O. results may reflect flows on the sampling days only.

Temperature Corrections for Critical Dissolved Oxygen

In constructing the D.O.-flow curve (Figure 1), it is desirable that D.O. results at different discharges be at the same temperature. As this is often impossible to arrange in stream surveys,

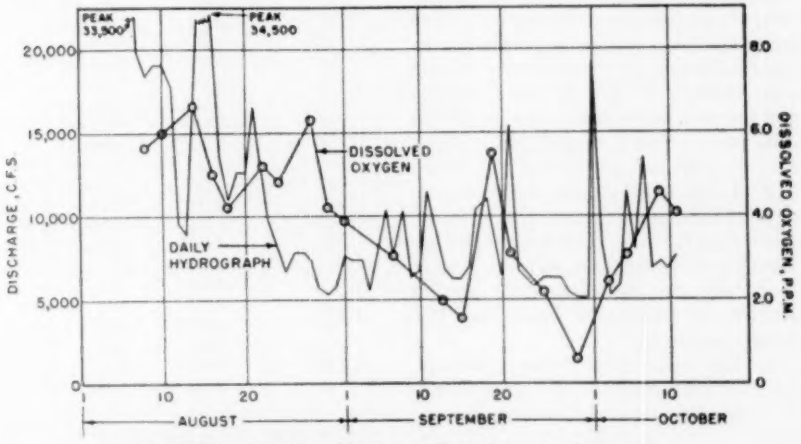

FIGURE 3.—Relation of D.O. to daily hydrograph of stream.

it is necessary to adjust or correct critical D.O. results observed over a period of time, say August to October, to a single design temperature, say 25° C. This adjustment for temperature can be made on the basis that the critical deficit below saturation, D_c, in p.p.m., will remain practically constant despite variations in temperature. The basis for this statement is as follows:

1. The temperature correction coefficient (1.047) for k_2 in the formula

$$k_T = k_{20}\,(1.047^{T-20}) \qquad (7)$$

is substantially the same as that for k_1 and, therefore, the ratio k_2/k_1 may be expected to remain constant with variable temperature, under any given set of conditions. This conclusion, that the two temperature correction coefficients are the same, has been borne out by studies of atmospheric reaeration by Streeter, Wright, and Kehr (6). The conclusion is also presented by Phelps (8). Investigators have found various values of the temperature correction coefficients for k_1 and k_2. However, the important matter in this discussion is the equality, rather than the exact numerical value, of the temperature correction coefficients for k_1 and k_2. The subject of the exact values of these temperature correction coefficients warrants more exhaustive future investigation. Supporting data for the establishment of temperature correction coefficients are strongest within the temperature range of 10° to 30° C. The temperature adjustment, therefore, is most reliable within this range.

2. There is no appreciable variation with temperature in L_a, the ultimate first-stage B.O.D. This conclusion has been borne out by Gotaas (7). Recent work at the Environmental Health Center in Cincinnati bears out this same conclusion.

3. The ratio k_2/k_1 being constant, and L_a being constant, Eq. 3a indicates that D_c must also be constant.

It is emphasized that adjustments in D.O. for temperature should be made only for critical D.O. data, as appreciable error may result if data at other than the critical point on the sag curve are adjusted. The bottom of the sag curve is usually rather flat and any errors will be quite small if the adjustment is applied to the lowest observed D.O. value.

The variation of the initial deficit, D_a, with temperature may conceivably have some slight effect on D_c. However, this effect on the temperature correction of D_c would be quite small in most cases.

The following is an example of adjustment of D.O. value for temperature: If the observed critical D.O. is 4.0 p.p.m. at 20° C., then the critical deficit is 9.2–4.0 = 5.2 p.p.m., and the critical D.O. at 25° C. would be 8.4–5.2, or approximately 3.2 p.p.m. Conversely, if the critical D.O. observed at 25° C. is 3.2 p.p.m. then the critical D.O. at 20° C. would be 4.0 p.p.m.

TABLE I.—Corrections in D.O. Values for Temperatures Ranging from 10° to 30° C.

Temperature, T (°C.)	Saturation Value, S_T (p.p.m.)	Correction[1] (p.p.m.)
10	11.33	Subtract 2.95
11	11.08	Subtract 2.70
12	10.83	Subtract 2.45
13	10.60	Subtract 2.22
14	10.37	Subtract 1.99
15	10.15	Subtract 1.77
16	9.95	Subtract 1.57
17	9.74	Subtract 1.36
18	9.54	Subtract 1.16
19	9.35	Subtract 0.97
20	9.17	Subtract 0.79
21	8.99	Subtract 0.61
22	8.83	Subtract 0.45
23	8.68	Subtract 0.30
24	8.53	Subtract 0.15
25	8.38	0
26	8.22	Add 0.16
27	8.07	Add 0.31
28	7.92	Add 0.46
29	7.77	Add 0.61
30	7.63	Add 0.75

[1] Correction $(S_T - 8.38)$ to convert D.O. results from T to 25° C.

Table I is a summary of corrections in D.O. values from temperatures ranging from 10° to 30° C. to a design temperature of 25° C. Similar correction tables can be prepared readily for any other design temperature that may be selected for local climatic conditions.

Conclusion

Before any estimates may be made of organic waste treatment requirements, certain basic decisions must be reached. A factor of judgment is required in determining such matters as design flows, design oxygen objectives, design temperature, and growth in population and industry. The determination of treatment requirements is not an exact science, nor do the prospects for its becoming so appear likely.

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AQUATIC WEED CONTROL WITH SODIUM ARSENITE

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Introduction

Aquatic vegetation has a definite role in the development and maintenance of a balanced aquatic community. A certain amount of aquatic vegetation in a given body of water is of value to the fishery, although no one has been able to determine the proportion of plant area to water area which is necessary for optimum fish production. Burdick (2) found that weed beds produced as much as four times the amount of food produced by weedless areas. Richardson (8) found the average productivity valuation from weed beds to be more than eight times the average of bottom hauls. Smaller snails formed 50 per cent of the total average by weight. The remaining 50 per cent consisted principally of small *Odonata*. Needham (7) observed that plant beds are 37.5 times as rich in food as bare pool bottoms. Klugh (6) stressed the value of plant productivity to such an extent that he proposed that rooted aquatic vegetation become the "index character" of the productivity of a lake. Surber (15) states that large amounts of submersed or emergent vegetation inevitably lead to overpopulation and stunted fish.

There are situations in which certain areas within a lake produce an overabundance of vegetation, which then becomes a weed in the true sense of the word. A nuisance develops from the profuse growth; property owners do not have free access to the main body of water by boat; there is an impediment to bathing and other recreational activity; the flow of water in streams, canals, and ditches is retarded; and the beauty of scenic areas is oftentimes impaired. Offensive odor, produced by the decomposition of large quantities of plant tissue, is the ultimate result of such growth. This may destroy recreational uses and jeopardize fish populations through oxygen depletion.

The intrinsic value of a lake can be enhanced through the control of the above-mentioned nuisances, provided adequate vegetation for the production of fish food is apparent in other areas. Thus, the idea of chemical control of nuisances was developed in Wisconsin. As a result of such control measures, the recreational assets of many bodies of water are multiplied many times.

Development of Chemical Weed Control in Wisconsin

A solution of sodium arsenite has been used for many years in aquatic weed control. In Wisconsin, Domogalla (3)(4)(5) reports the use of sodium arsenite for the control of weeds in the Madison lakes in 1926 and in following years. This is the first indication that sodium arsenite had been used for the control of a nuisance and the enhancement of the recreational value of an area. Surber (11) was the first to adopt this means of control in fish management work, stating that preliminary experiments with sodium arsenite during the summer of 1929 indicated that this chemical may be used effectively at low cost in controlling submerged aquatic plants without doing apparent injury to either large or small

fish and without exterminating or seriously diminishing the supply of natural foods.

In Wisconsin, during 1938, a controversy arose between sportsmen and property owners over the chemical treatment of a particular lake. Following this controversy, an executive order established a committee to review the problem of algae and weed control in streams and other bodies of water in the state. The personnel of the original Wisconsin Committee on the Chemical Treatment of Lakes and Streams consisted of an attorney of the Wisconsin Public Service Commission, the chief biologist of the Wisconsin Conservation Department, the chief chemist of the State Laboratory of Hygiene, and the State sanitary engineer of the State Board of Health. The Committee has since been modified to include the State sanitary engineer of the State Board of Health, the chief chemist of the State Laboratory of Hygiene, and the assistant director of the Wisconsin Conservation Department. The principal function and aims of this Committee are:

1. To investigate the technical aspects of the use of chemicals in order to determine whether or not, and to what degree, the practice of treatment is detrimental to lakes.

2. To disseminate information on the subject as an educational service toward resolving controversy and particularly that surrounding proper proposals for chemical treatment.

3. To supervise nuisance control activities wherever conducted in the State.

Soon after the formation of the original Committee, a permit system was devised making it necessary for the filing of an application with the Committee on the Chemical Treatment of Lakes and Streams for chemical control.

In 1941, the legislature passed an act calling upon the Committee on Water Pollution ". . . to supervise chemical treatment of waters for the suppression of algae, aquatic weeds, swimmers' itch, and other nuisance-producing plants and organisms. To this end the Committee may conduct experiments for the purpose of ascertaining the best methods for such control. It may purchase equipment and may make a charge for the use of the same and for materials furnished, together with a per diem charge for any services performed in such work. The charge shall be sufficient to reimburse the committee for the use of the equipment, the actual cost of the materials furnished, and the actual cost of the services rendered plus 10 per cent for overhead and development work."

The first chemical weed control under Committee supervision was instigated in Lake Wapogasset near Amery, Wis., in 1939. A barge propelled by paddle wheels was used in the distribution of the chemical. A concentration of 2 p.p.m. white arsenic equivalent was ineffective in killing the plants. However, a concentration of 4 to 6 p.p.m. white arsenic equivalent was used in a bathing beach area with more encouraging results.

State-owned equipment was purchased in 1941 and operated on a rental basis for the chemical control of aquatic nuisances. The growth of the early program was governed by the ability of the crew operating the state-owned equipment to treat as many of the proposed projects as possible at a time when treatment was biologically necessary for best results. It was soon found that this type of procedure could not keep abreast of the demands for control.

The Committee felt that enough experimental work had been done and it was no longer necessary for the state to make the actual treatment. Therefore, in 1949, state-owned equipment was not used on any of the treatment projects. Sponsoring organizations could elect one of two options in con-

ducting the work—that is, they might enter into private contract with one of the approved operators in the field for the completion of the project, or the sponsoring organization might apply the chemical by using their own equipment, providing such equipment was found to be suitable for the application of chemicals. In either case, an application for permit to carry out chemical treatment control is filed with and approved by the Committee on Chemical Treatment of Lakes and Streams. The actual treatment must be under the direct supervision of a representative of the Committee on Water Pollution and a charge is made by the Committee to defray the cost of this supervision. It is a function of the Committee on Water Pollution to determine that conditions existing in the area actually constitute a nuisance, as chemical treatment must be authorized on the basis of such findings.

As previously stated, the program of chemical control of submergent aquatic vegetation had its beginning in 1939 with one treatment project. In 1940, four projects were supervised, and in 1941 the number had risen to six. During the following three years, 1942–1944, there were only three treatment projects scheduled. The year 1945 saw the beginning of an accelerated program. In this year, there were seven lakes treated for weed eradication; in 1946, 12; in 1947, 18; in 1948, 20; and in 1949 there were 33 weed treatment projects. This represents an increase between 1945 and 1949 of 371 per cent, and an increase between 1948 and 1949 of 65 per cent. The 33 treatment projects in 1949 used a total of 8,643 gal. of commercial sodium arsenite solution.

Control Methods

In Wisconsin, chemical weed control has as a primary aim the relief from a nuisance and the increase in recreational value of a localized area. It is limited, therefore, to a marginal strip of 200 to 300 ft. along a portion of the shoreline of a lake, the cutting of channels through weed beds so that boats will have access to deeper water, and the control of vegetation around piers. The Committee does not approve or recommend complete destruction of aquatic vegetation in a lake, but insists on leaving untreated reserve areas adequate for fish food production.

Surber (14) found that dosages of 1.7 to 4.0 p.p.m. white arsenic equivalent was effective in controlling practically all submerged flowering plants in fish ponds, but did not affect fish. Because the majority of the work done in Wisconsin is on larger bodies of water, the concentrations used are somewhat higher. Commercial sodium arsenite containing 4 lb. of white arsenic per gallon is used in all treatments. In the event that an entire small body of water is treated, a dosage of 5 p.p.m. white arsenic equivalent is used. It has been found effective in treating fish management ponds containing walleye fry to attempt two treatments; that is, one-half of the pond is treated one week later than the first half. In the treatment of the shoreline area of a large body of water protected from wind and wave action and having an average depth not exceeding 5 ft. and a maximum depth not exceeding 8 ft., a dosage of 7.5 p.p.m. white arsenic equivalent is recommended. A dosage of 10 p.p.m. white arsenic equivalent has been found effective against submergent vegetation in the treatment of a shoreline area of a large body of water unprotected from wind and wave action and having an average depth not exceeding 5 ft. and a maximum depth not exceeding 8 ft. Shoreline areas in which the depth of the water exceeds 8 ft. have not been found suitable for treatment. The majority of the projects in Wisconsin require the higher dosage in order to insure effective control.

In determining the amount of chemi-

cal required for the treatment of large areas, it is advantageous to subdivide the area into small sections and calculate the amount of chemical required for each section separately. This will permit an even distribution of chemical in order to maintain a desirable concentration of the weedicide, which is very important to insure an adequate kill. The calculation of the amount of chemical required to adequately treat any given area is based on the weight of water to be treated.

The equipment used in distributing sodium arsenite consists of a reservoir to hold the commercial solution, a pump to draw water from the lake or stream, as well as chemical solution from the reservoir, and a nozzle through which the diluted mixture is directed uniformly over the water surface. For best results, it is necessary to accomplish an even distribution of the chemical over the area to be treated.

Arsenical compounds are recognized poisons; therefore, certain precautions should be observed in its application. The shoreline area should be treated first. Fish and other aquatic organisms are repelled by sodium arsenite and are stimulated to leave the treatment area. Thus, they are exposed to the chemical for only a short period of time. In treatment of the shoreline strip, care should be used so that trees and shrubs growing on the bank will not be sprayed. The hands of the operator should be protected with rubber gloves and it is important that the wind be in such a direction that the spray will not blow against the operator's face and cause a burn. The application of face cream prior to spraying has been found helpful in alleviating this condition. It is considered good practice, as a safety measure, to advise against the use of treated water for bathing, watering lawns, or the use of water for livestock or pets for a period of 2 or 3 days following application of the chemical. At the end of that time the chemical should be sufficiently dissipated by dilution and absorption to make similar precautions no longer necessary.

Effects of Treatment

The time necessary for weed destruction after the application of chemical is usually about 7 days. Sodium arsenite solution has been found efficacious in the destruction of arrowhead; water plantain; bladderwort; coontail; waterweed; wild celery; common, bushy, and horned pondweeds; water crowfoot; water milfoil; and other plants. Surber (13) states that water lilies and lake bulrushes cannot be destroyed with a reasonable amount of sodium arsenite. He further states that chara are very resistant to this chemical, but can be destroyed readily by the use of copper sulfate. The work in Wisconsin concurs with the above findings. Following destruction, the weeds sink to the bottom and remain in place in the bottom muds. Treatment should be initiated when the weeds are young and growing vigorously, so that a maximum amount of chemical will be absorbed by the plant cells. This also will reduce the possibility of an oxygen depletion caused by the decomposition of a large mass of plant tissue. The rate of decomposition is usually so slow, however, that the oxygen balance is not greatly distorted.

There is no reason to suspect a deleterious effect on the fish life because of the use of a sodium arsenite solution for weed control. Tests by the Wisconsin Committee on Water Pollution (19) showed that largemouth bass were unaffected by the chemical in concentrations of 6 p.p.m. for 10 days. A concentration of 10 p.p.m. killed 13 per cent of the fish in the same length of time. Bluegills and crappies were found to survive 12 p.p.m. for 6 days. A similar test in distilled water indicated that sodium

arsenite has the same effect on fish in either hard or soft water. Wiebe (18) found that 7 p.p.m. white arsenic equivalent in Mississippi River water did not injure the fingering stages of smallmouth bass, largemouth bass, white crappies, golden shiners, bluegills, bullheads, and goldfish upon exposure for 148 hr. Surber and Meehean (16) found that chironomids, mayfly nymphs, and fresh-water shrimp appear to be the most sensitive to the treatment, with relatively high mortality rates following exposure to 2.5 to 4.0 p.p.m. white arsenic equivalent. Damselfly and dragonfly nymphs, sow bugs, and water mites survived concentrations of 10.5 to 21 p.p.m. Safety factors are in operation following treatment, which reduces the concentration to which aquatic organisms are exposed. Fish and some aquatic organisms are repelled by the chemical, and the concentration of the chemical in a localized area is progressively decreased by diffusion into untreated areas by wave action and by absorption by the vegetation and the bottom muds.

Summary

1. Commercial sodium arsenite has been effectively used in the destruction of certain species of aquatic vegetation and the eradication of localized nuisances without harm to the fish life present. Its use in Wisconsin has been authorized and supervised by an interdepartmental State committee for the past 10 years.

2. Dosages up to 10 p.p.m. are recommended, depending on the physical character of the area to be treated.

3. A history of the development of the program in Wisconsin is given in detail, as well as the method of application and the effect of such application on aquatic vegetation and aquatic organisms.

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TREATMENT FINANCING IN NEW YORK STATE

All but a handful of New York State municipalities will be able to build sewer systems and sewage treatment plants and thus cease polluting the State's surface waters if a proposed constitutional amendment is approved by the 1951 legislature, and ratified by the electorate. Under the State's water pollution control program, enacted in 1949, a Water Pollution Control Board has been established, with authority to order municipalities and industries to cease polluting surface waters. One of the problems which remained to be solved, however, was that of the municipalities which are now discharging raw sewage into surface waters, and do not have sufficient debt margin, under constitutional debt limitations, to construct treatment works.

In order to meet their problem, the 1950 session of the legislature approved a proposed constitutional amendment, under which municipalities can exempt from their debt limits up to 75 per cent of the cost of sewer systems and sewage treatment works, if, through the use of sewer rentals or similar devices, they can be shown in the blueprint stage to be self-sustaining.

It is estimated that if the bill becomes law, only 25 municipalities, all villages, will be fiscally unable to proceed with the construction of sewage treatment plants. Earlier studies had shown that, because of debt limitations, 6 cities, more than 90 villages, and 13 town would be unable to build treatment plants, even if ordered to do so by the Water Pollution Control Board.

In addition to providing for advance exclusion of the cost of sewage facilities, the proposed amendment will substitute the 5-year average full valuation for the 5-year average assessed valuation as the base for the debt limit, and revise or re-establish percentage limitations on the indebtedness of counties, cities, towns, and villages.

PRESSURE COOKER STREAM SAMPLER*

By A. C. Hyde

Chemist, E. I. du Pont de Nemours Co., Belle, W. Va.

Experience with several conventional types of displacement river sampling devices has led to undue expense and mechanical difficulties. The chief trouble has been in making a watertight seal between the lid and body of the vessel. The quest for a simple and effective seal that could be easily operated in the field led to the use of pressure cookers, with simple modifications to fit them to the purpose intended.

A commercial 4-qt. cooker was selected because the internal height of the vessel will accommodate standard B.O.D. bottles. The cooker retails for $12.75, and approximately 4 hr. of shop work are required to make the conversion.

Two ⅜-in. holes are drilled 3½ in. apart in the lid and connect with aluminum downpipes that extend to within ¼ in. of the bottom of the sample bottles. The handle, of aluminum tubing, is welded on the lid so as to cover the rubber rupture disc hole. The cooker vent, as furnished, serves as an air vent on the sampler without further modification. Approximately 7 lb. of lead are bolted to the bottom to give enough weight to assure rapid sinking. The sampler fills in 90 sec. at a 15-ft. depth, the volume allowing displacement of each bottle 5 times.

* Presented at 1949 Annual Meeting, West Virginia Sewage and Industrial Wastes Assn.; Wheeling, W. Va.; Sept. 20–22, 1949.

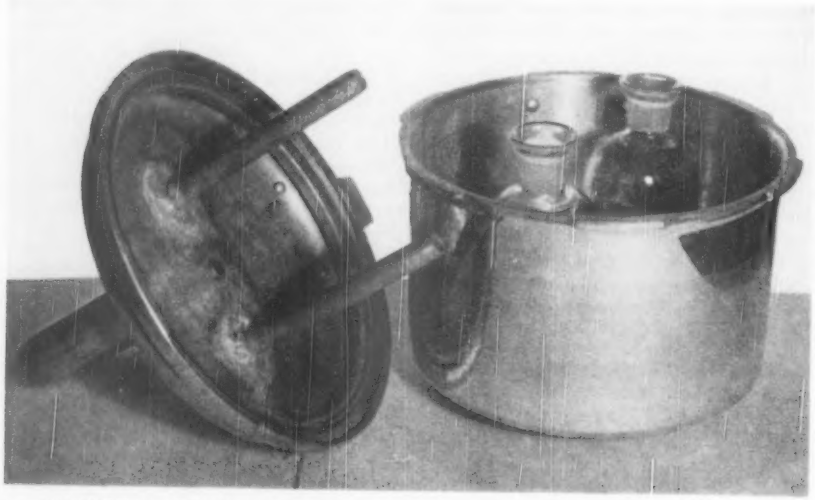

FIGURE 1.—Effective stream sampler made by simple adaptation of household pressure cooker.

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

CREDIT DUE—CREDIT GIVEN

High praise, indeed, was showered on the North Shore (Ill.) Sanitary District when the Illinois Izaak Walton League recently honored District officials for eliminating pollution of Lake Michigan in the area around Waukegan, Ill. The conservation society presented officers of the Sanitary District with its "Sanitation Award," established to provide recognition for public officials and industrial leaders in Illinois who go beyond the ordinary call of duty to perform an outstanding job, in ". . . public recognition of their outstanding progress toward the control of water pollution in Illinois."

Specifically cited during the presentation ceremonies were: R. E. Anderson, chemist-engineer of the District, for his surveys of plant performance and Lake Michigan waters; Matt Kirn, superintendent of the sewage treatment plant at Waukegan; and L. K. Ekstrand, superintendent of sewage plants outside the Waukegan area.

This, so far as is known, is the first such recognition accorded a public body by a statewide sportsmen's organization. The only similar award, also a plaque given early this year by a local Waltonian group, was presented to the American Viscose Corp., of Front Royal, Va., which ". . . through its pollution abatement efforts restored to usefulness and beauty a stream that had been made a biological desert by uncontrolled industrial pollution."

Presentation of these awards should certainly be heart-warming, not only to workers in the stream clean-up program, but also to municipal and industrial treatment plant operators and administrators, whose heroic efforts to do the very best job possible with the too often inadequate equipment and insufficient appropriations furnished them generally go unrecognized or are unconsciously classified as "routine." Here is "battlefield" recognition of front-line accomplishment in the far-flung campaign.

More than that, it is an indication that the Waltonians, so often regarded as being idealistic, impractical, and unreasonable, because of their demands on water quality, stand ready to give credit where credit is due in stream sanitation affairs. Evidence has been provided that the reputation gained by the League and its local groups may need reappraisal in the minds of many. To incessantly demand "more" and "better" and "highest" is one thing; to follow up with public recognition of accomplishment or outstanding progress is another. It not only shows that local efforts are under critical scrutiny, but that the effects of local effort on the broad picture also are being taken into consideration.

To the recipients of the two awards, a hearty "Well done!" for exceptionally fine jobs in practical pollution abatement matters. Operators everywhere may feel pride in the accomplishments of these colleagues who have been singled out for this high "decoration."

H. P. O.

THE EFFECT OF INDUSTRIAL WASTES ON SEWAGE TREATMENT AT TOPEKA, KANSAS *

By D. B. Kissinger

Superintendent of Sewage Treatment, Topeka, Kans.

Because this paper deals primarily with industrial wastes and their effect on sewage treatment at Topeka, the three sewer systems that discharge directly to the river, and North Topeka's system that goes to an Imhoff tank, will be disregarded; they do not handle any appreciable wastes from industry. The population tributary to the East Side treatment plant, which handles industrial wastes, is about 50,000.

Plant records for 1949 show an average load, from Monday through Friday, of 13.3 tons of B.O.D. per day, or a population equivalent of about 156,000. However, including Saturdays and Sundays brings the average down to 11.9 tons of B.O.D. per day, or an equivalent population of about 140,000 people.

In a report on an extensive survey of Topeka's sewage problems made in 1946, a consulting engineering firm says that the B.O.D. load on the East Side treatment plant had a population equivalent of 139,000 people, or about 11.8 tons B.O.D. per day. This is within 0.1 ton B.O.D. per day of the plant average for 1949. The report can still be considered to give the true picture of Topeka's sewage conditions as of 1949.

Origin of Wastes

The report traces the source of the major pollution load entering the sewers. The greatest load comes from a meat packing plant that processes cattle, hogs, and sheep. Its normal daily capacity of 175 to 200 cattle, 1,850 hogs, and 5,000 sheep was judged to have a population equivalent of 56,000, or about 4.8 tons B.O.D. In 1946, the B.O.D. concentration during the test period was 1,000 p.p.m. No ether soluble tests were taken. However, several grab sample tests were made in February, 1950, because the B.O.D. load at the treatment plant had dropped from the daily average of 11.9 tons for 1949 to 9.3 in January, 1950. The grab sample tests averaged about 1,000 p.p.m. B.O.D. and the ether soluble test also showed an average of approximately 1,000 p.p.m. Inquiry at the packing plant revealed that the daily kill had been reduced to an average of 1,250 hogs, 85 cattle, and no sheep. Based on this meager evidence and some other grab samples, it is believed that this plant's waste would contain 1,000 p.p.m. B.O.D. of which a very large percentage is attributable to grease in a saponified form.

The second greatest load comes from a packing plant processing about 625 horses in a 5-day week. Because the plant has several connections to a large interceptor running beneath it, it is impossible to closely analyze the contributed load without a more extensive survey than present facilities permit. It is known, however, that during 1949 all of the raw blood and stock pen cleanings, and even parts of animals that would be retained on a 6-in. screen, were dumped into the sewer. The 1946 survey report states that this plant could be operated so it would only impose a load of 1 ton of B.O.D. per day, but it is believed that this value was greatly exceeded in 1949.

A chicken packing plant operating in Topeka killed 675,000 chickens in 1949. Of this quantity, 75 per cent

* Presented at 1950 Annual Meeting, Kansas Sewage Works Assn.; Salina, Kans.; April 19–20, 1950.

were killed between June and December. From the 1946 survey report, this load, under careful operation, would have a population equivalent of 1,600 people, or about 0.1 ton B.O.D. per day. This also is a conservative value, for the waste contains an appreciable amount of blood and some of the manure from the hold-over room.

The largest non-packinghouse source of pollution is a creamery. It has been judged to produce a population equivalent B.O.D. load of about 3,000 people. There are a number of other small milk processing plants and chicken dressing establishments, which would increase the population equivalent load by another 2,500 people. This, with the large creamery load, would be about 0.5 ton B.O.D. With the packing plants, creameries, etc., contributing approximately 5.4 tons of B.O.D., 6.5 tons remain to be accounted for by the other 50,000 people the East Side plant serves.

Normally, the load on the system would be figured at 0.17 lb. B.O.D. per capita per day; however, prorating the unaccounted for 6.5 tons over 50,000 people gives a B.O.D. load equal to 0.26 per person. On the other hand, examination of two sewers serving a residential section of Topeka reveals a B.O.D. load of 1,308 lb. per day from 18,550 people, or 0.07 lb. B.O.D. per person per day. From these values it would seem that the calculation of industrial load has been quite conservative or that some industry imposing a considerable load has been missed. It is quite strongly suspected that the former is the case.

Volume of Wastes

It will be noted by now that no mention has been made of volume of sewage. In the industries about which Topeka is concerned, from all but one waste source, strength overshadows volume to such an extent that it is of secondary importance. The one exception is the summertime air conditioning flow of 2 m.g.d., which should go to storm sewers, as there is little reason to add the uncontaminated cooling water to the sanitary sewers. For the record, however, the packing plant that handles cattle, hogs, and sheep has about 1.1 m.g.d. flow; the horse packing plant, which had 1.1 m.g.d. flow in 1946, has modified its plant operations so that the estimated volume is about 0.7 m.g.d.; and the chicken packing plant has a flow of about 0.4 m.g.d. The total packinghouse flow, therefore, is about 2 to 2.5 m.g.d. This sewage is mixed with domestic and semidomestic sewage to make a total of 7.6 m.g.d. with an average B.O.D. of 376 p.p.m.

During 1949 all samples were taken and composited for the full day. As a result, no breakdown was possible for parts of the day. During January and March, 1950, the tests were run for 8-hr. periods. The average B.O.D. for the first 8 hr. of the day was 120 p.p.m.; for the second 8 hr., 450 p.p.m.; and for the third 8 hr., 245 p.p.m. The volume loads for the same periods were 2, 3, and 2.7 m.g. respectively.

Effect on Activated Sludge

In the operation of an activated sludge plant it is very helpful to know the B.O.D. load being imposed on the aerators immediately—not what was imposed five days ago. Although the writer has heard of quick methods of determining B.O.D., he has no first-hand knowledge of them. The next best method is to attack the problem from the standpoint of the law of averages. Inspection of the mass of collected data revealed that the sewage strength in any one shift could vary from the average by several hundred per cent. Nevertheless, by regrouping the figures for all the days of the week under the day of the week on which the tests were made, it was found that the loads coming to the

plant followed a distinct pattern. After passage through the primary settling tanks, it was found that the consistency of the pattern was more pronounced than ever. By dividing the B.O.D. load for each shift by the flow for that shift, a value was obtained for the expected tons of B.O.D. per m.g. of flow.

On the basis of the effluent from the primary tanks in January, 1950, it was predicted that in a 28-day period in March, 115.4 tons of B.O.D. were sent to the aeration tanks. Laboratory analysis showed the actual aeration tank loading to be 117.7 tons of B.O.D. Two-thirds of the daily tests varied very little between actual and predicted. The other third of the daily tests varied up to 3 tons, but were so scattered among the more accurate predictions that it has been of value to use this method. However, it does not replace the experienced eye of the operator, who can detect marked changes in the sewage load and change the aerator feeding when he believes an adjustment should be made. It should be added here that Topeka does not give secondary treatment to all the sewage coming to the East Side treatment plant. However, in 1949 about two-thirds of the B.O.D. tonnage received at the plant was removed.

Foaming and Rising Sludge

Lately there have been several discussions published on the causes of aerator foaming. The Topeka aerators foamed off and on for years—so badly that the whole area for many feet away from the aerators was covered several feet deep with a white foam. It is thought that this was caused by a condition of the sludge brought about by loading an aerator to its capacity with a sewage of high grease content and then feeding an excess of air to the mixed liquor. It is doubted that the tanks ever foamed without a high D.O. content in the mixed liquor, as there is seldom any foaming in the first pass of the tanks; it starts in the second pass, and when the third pass is reached, is in full bloom. A change in the aerator feeding plan (from one-point feeding to feeding in all three passes) is expected not only to reduce the foaming, but also to increase the aerator capacity.

A recent report of the difficulties encountered in operation of an activated sludge plant treating high protein wastes from meat packing (see THIS JOURNAL, **22**, 6, 807; June, 1950) describes the so far unsolved problem, at this plant, of a rising sludge blanket in the final clarifiers. Originally, Topeka had this problem, which was never completely solved until 1944, when the Mallory process was installed. Although this process was not adopted completely for the Topeka plant, there has been no further trouble with the rising sludge problem. However, the aerators were operating at below capacity loads. Adaptation of the Mallory process fundamentals has developed an empirical method of controls that allows a considerable increase in aerator loading without causing rising sludge.

The point that should be emphasized in this discussion on industrial sewage is not the horrors of the continued shock loads facing the operator of a plant treating industrial sewage, but the steady day to day pressure on the plant operator that makes solution of the problem imperative.

HANDLING RADIOACTIVE WASTES IN SEWERS *

By John D. Parkhurst

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Types of Radiation

Natural Radioactivity

In 1896, Henri Becquerel found that certain uranium salts emitted penetrating radiations. A few years later, Pierre and Marie Curie announced that they had succeeded in isolating from pitchblende, a uranium mineral, two substances that were many times more radioactive than uranium. These new substances were shown to be two new elements—polonium and radium. It is important to emphasize that these radioactive elements emit radiation spontaneously without the addition of energy to them.

Since then, at least 14 other naturally radioactive elements have been found. Such radioactive elements are now known to be intimately related to each other in what is called the "radioactive series." These naturally radioactive elements' emissions have come to be known as alpha radiation, beta radiation, and gamma radiation.

Artificial Radioactivity

In 1934, Jolliot and Curie observed that when aluminum was bombarded with alpha particles from polonium, neutron and positron emission did not cease immediately upon removal of the alpha source. Instead, the positron activity decreased exponentially with time in the same way as natural radioactivity. Today, every element in the periodic system has at least one radioisotope, and about 450 induced radioactivities are known. Some of these, such as C^{14}, P^{32}, and I^{131}, are well known for their application to medical research and therapy. It is now known that artificial radioactivity can be induced by many reactions other than alpha bombardment.

The Problem

Whereas the use of natural radioisotopes had confined the experimenter to alpha, beta, and gamma radiation of rather limited energy and intensity, the advent of artificial radioisotopes opened up a whole new field of nuclear physics. A very rapid increase in production and variation of usage of radioisotopes has followed World War II.

Unfortunately, man's knowledge and understanding of radioactive waste disposal, the hazards involved, legal responsibilities, and effects on living tissue, has not kept pace with the widespread usage of isotopes. None of the tests generally indicative of a contaminant in air, water, or food and commonly applied to industrial waste will reveal presence of radioactivity. Secrecy of purpose makes the waste disposal problem far more difficult of evaluation and correction.

Hazards

Again, unfortunately, the exact mechanism by which radiation harms living molecules, cells, and tissues is not sufficiently understood. Some forms of radiation may cause greater amounts of damage, but the general type of injury is the same. Mitosis, or cellular division, which goes on constantly in the body, is interrupted by the ion path created by a radioactive particle. This ion path, depending on its strength, may be lethal to the cell, or may cause a point mutation in the genes, thus causing development of a hybrid.

Many activities are under way seeking to provide data upon which to

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evaluate the effects of different radiations and establish approximate standards and rules, but the investigators are deeply aware of a lack of basic, fundamental knowledge of radiation effects. Medical research has not discovered any treatment which, for the moment, will neutralize the tissue damage of radioactive materials in the body tissues. Because of the lack of knowledge, a very conservative attitude toward control methods must be exercised.

In evaluating the hazards of radiation, it is important to emphasize the fact that very small concentrations of many radioisotopes produce tolerance doses.

Methods of Disposal of Radioactive Waste

The problem of disposal of radioactive wastes from its large installations has long been a major item in the program of the Atomic Energy Commission (AEC). With the rapid increase in use of radioisotopes throughout the world by industry, medical institutions, research laboratories, and many other agencies, the problem has become equally important to the local authorities.

Artificial radioisotopes are manufactured at the Atomic Energy Commission's installations and shipped to the purchaser for use. Although the Isotopes Division of AEC carefully investigates all requests for isotopes prior to shipment, it does not permit return of radioactive waste to the commission for disposal, nor does it assume responsibility for disposal of radioactive waste except at AEC installations.

Because the disposal of radioactive wastes is a considerable problem to recipients outside the AEC laboratories, the National Committee on Radiation Protection has established a Subcommittee on Waste Disposal and Decontamination. The subcommittee is to study the broad problems of disposal and make recommendations applicable to the disposal of all radioactive materials by off-Commission users. So far as is known, this report is not yet available.

During the interim period, the Isotopes Division has published its Isotopes Division Circular B-6, "Interim Recommendations for the Disposal of Radioactive Wastes by off-Commission Users," available through the U. S. Atomic Energy Commission, Isotopes Division, P.O. Box E, Oak Ridge, Tenn. The U. S. Department of Commerce, National Bureau of Standards, has published Handbook 42, "Safe Handling of Radioisotopes," which is for sale by the Superintendent of Documents, Washington, D. C. (price 15 ¢).

Radioactivity in the form of radioisotopes may reach the sewer in a number of ways. First, it may be present in excreta from patients being treated at hospitals, clinics, or medical offices. If an isotope is used in therapeutic treatment, large amounts of the radioactive waste may appear in the excreta and urine of the patient, usually within 24 hr. after ingestion.

Second, it may arrive at the sewer in the form of a chemical waste from a research laboratory. Under the "Interim Recommendations," radioiodine may be discharged from an institution provided the sewage flow from the outlet is sufficient to dilute the radioiodine to 0.5 microcurie per liter. Radiophosphorus may be discharged to the sewer provided the sewage flow from the outlet is sufficient to dilute the radiophosphorus to 0.1 microcurie per liter. Both of these dilutions are contingent, however, on other specifications as to chemical form, total discharge per week, and nature of final sewage disposal.

Third, it may appear from miscellaneous sources, such as industrial waste, rinse waters from washing operations, and accidental spillages.

In operating sewers possibly con-

taminated with radioactive materials, safety must always be the primary consideration. Maintenance personnel whose job may require entrance into manholes and treatment works must be protected from external exposure to radiation. Treatment plants disposing of digested sludge as fertilizer must be prepared not to exceed safe concentrations of radioactive material if the fertilizer is to be spread in public parks, citrus groves, or any place unrestricted to the public use.

Control

Radioactive isotopes can be distinguished by the half-life of the isotope and the type of radiation given off. Fortunately, many of the pile-produced isotopes have relatively short half-lives, varying from a few seconds up to several days. Unless the volume of waste is extremely voluminous or obnoxious, it is a relatively simple matter to store the waste at its point of origin for a period of 10 half-lives prior to discharge into the sewer. At the end of this storage period, the specific activity of the waste will be less than 1 per cent of its initial activity.

Radioisotopes with long half-lives cannot be economically stored for a period of 10 half-lives unless the quantity is very small. The "Interim Recommendations" state that each isotope should be examined individually as to physical characteristics and chemical and biological behavior. Disposal can then be accomplished by one of two general methods—dilution and dispersion, or confinement and control.

Dilution and Dispersion

Dilution of radioisotopes may be with stable isotopes of the same element in the same chemical form, or with media other than stable isotopes of the same element (with air, water, etc.). Extreme care must be exercised in the latter method, as reconcentration of the radioactivity by chemical, physical, or biological means must be considered.

Confinement and Control

Confinement of radioactive wastes is usually preceded by either dilution or concentration. Dilution is with concrete, for burial at sea; concentration is by evaporation, precipitation, ion exchange, or incineration.

Burial grounds for final storage of long-lived materials must be carefully protected and jurisdiction maintained for a long period of time. In this connection, it seems desirable for a community burial ground to be maintained by a local authority and made available to all users of isotopes, rather than to permit individual grounds for each user.

Disposal of long-lived materials by dilution with concrete and burial at sea appears to be most suitable for metropolitan areas not too distant from the ocean. This again should be a community enterprise—most logically by the same local agency charged with disposal of other industrial wastes.

As already mentioned, none of the usual methods of testing industrial waste will detect the presence of radioactivity. Special electronic instruments (with circuits sensitive to the ion path created by the radioactive particle) are required. Two types of these instruments appear to be best suited for use in the field. The first, commonly known as a "beta-gamma survey meter" is a portable detection instrument making use of a Geiger-Müller tube. This instrument, when used with earphones, is quite sensitive and capable of locating even small amounts of contamination. Although it is equipped with a scale to register radiation in terms of milli-roentgens per hour, it is probably not too satisfactory for this purpose. The Geiger-Müller tube is said to become paralyzed when exposed to strong sources of radiation.

The second type of meter is known as a "radiation hazard meter." This instrument, sometimes called the "Cutie Pie," utilizes an ionization chamber as the detection device in place of the Geiger-Müller tube. The instrument is not paralyzed by a strong radioactive field and gives quite accurate readings over a wider range. This particular instrument is most useful in determining permissible exposure time in an unknown radiation field. Both types of instrument are available in several different models and are manufactured commercially by a half dozen or more companies. It should be noted that both instruments are sensitive to beta-gamma radiation only. If it is suspected that the contamination is an alpha emitter, an "alpha survey meter" must be used. This type of meter has been made available commercially only recently.

The permissible whole-body radiation, or tolerance dose, is highly debatable. In the United States, 0.1 roentgen per day is considered safe for workers who receive repeated doses in connection with employment, whereas England permits 0.2 roentgen per day and Canada has set the level at 0.05 roentgen per day.

Whatever the permissible exposure may be, it cannot be too strongly emphasized that any amount of radiation is potentially dangerous and should be avoided whenever possible. No one should feel that he can receive the tolerance limit of radiation with safety and permit exposure when it may be avoided. To be specific: if a single ionizing event is able to produce an altered heredity in offspring through injury to a gene, it is evident that even a single radioactive particle is potentially dangerous and that a reduced exposure merely reduces the chance of injury.

THE DAILY LOG

Aurora, Illinois

By Walter A. Sperry, *Superintendent*

February 16—Shades of Izaak Walton! Here is a bullhead story for the books. The City of Aurora controls a large intercepting sewer, which begins in the northwest section of the city at 4-ft. diameter and discharges into Fox River at 8-ft. diameter. Its upper end is bar-screened to eliminate trash and receives the full flow of a sizeable creek. At its river end, the sewer overlies the Sanitary District's main interceptor, to which dry-weather flow passes through a 12-in. by-pass. Storm water jumps a dam to the river.

Early in 1949 a spring rain caused a freshet in the creek. The increased flow washed from the creek's pools a considerable number of bullheads 2 to 4 in. long. The bullheads survived the sewage bath, passed through the clarifiers and pumps, and lodged in the sprinkling filter nozzles before we realized what was happening. The entire four acres of nozzles were almost completely plugged. It took four men almost two days to hook the fish out with bent wires before order was restored. Such a phenomenon had never before happened.

This spring we were not caught. A similar spring freshet again brought down the bullheads. They swam all over the clarifiers and were netted out—a big bucket full—and returned to the river. Thus we avoided a messy, smelly job still remembered with distaste.

February 24—An interesting new use has been found for defective concrete burial vaults. The April 20, 1950,

issue of the *Engineering News-Record*, pp. 32–35, carries an interesting and valuable, though embarrassing, story. The U. S. Public Health Service reports the results of a comprehensive study of some 18 forms of septic tanks of many and diverse shapes, most of which are radically different from traditional types planned by most State Health Departments. Contrary to your Logger's many cautions to guidance-seeking citizens to use only state plans and to avoid proprietary types generally offered by plumbing shops, it now appears that any and all forms are equally efficient. Yesterday we were told that many householders in a nearby local housing project are saving money by using defective concrete burial boxes, with lids, as septic tanks, and that they do a good job.

March 2—A maintenance note of a valuable material to be filed for future use. We have two automatic lift stations downtown that remove sewage from an island to the interceptor on the mainland. In each of these stations the two pumps are located at the bottom of a 20-ft. deep caisson chamber. The pumps are serviced twice a week and the removal of leakage water collecting in the caisson is often a problem. In both stations serious leaks developed in the suction lines between the caisson wall and the wet wells. Repairs appeared impossible due to the close quarters. The leaks were successfully stopped by the use of "Water Plug" (Dry Wall Products Co., Eagle, Pa.), which flash sets in 3 min. against water pressure if necessary. A block of the material was molded by hand around each of the leaking spots, the material being held in place until the set occurred. The base of the material appears to be Portland cement, but ordinary cement could not have been used.

March 10—Today we received a check for our share of our 1949 corn crop. Some nine acres of front and back fields of the plant grounds are generally cropped with alfalfa. A local farmer cuts the resulting hay three times a year on shares. Thus, the unused parts of the plant grounds remain an attractive green, with the weed problem controlled. Every four to six years, however, crop rotation is necessary. In 1949 a hybrid corn was planted. The yield, about 40 bu. per acre, was sold at $1.00 per bushel, on the ear; our share was $165. Soy beans have been purchased for the 1950 planting to further control weeds and quack grass before returning the area to alfalfa.

March 15—This bit of digester operation history is illuminating. Today we got out the long sampling pole and inventoried the digesters. The No. 2 digester showed a sludge line at 109 in. and had a run of 150 days since the last discharge. The No. 3 digester sludge line stood at 145 in., with a run of 190 days since the last discharge. As the "full" line is 163 in., at which point the sludge line approaches the supernatant overflow outlet level, both digesters could yet run many days before discharging to the sand beds. The total solids averaged 10 per cent, the volatile solids 42.6 per cent, the specific gravity 1.046, and the pH 6.65.

Prior to the installation of the largest wallpaper printing plant in the U. S. as a neighbor—with a clay discharge from the color pots to our plant—these same digesters scarcely averaged 50-day runs. Then they had a total solids content of 5 per cent or less and a volatile content of 55 to 60 per cent. In 1949, as a direct result of clay loading, the digester runs between discharges averaged 106 days. The digester condition noted today was the combined result of clay loadings and a lean sewage due to unusual rain. Consequently, the gas was low and the digester temperatures were below normal.

March 31—Figure 1 is the tangible evidence that the 21 diaries that have accumulated since 1930 exist. They

are kept in the safe at the Aurora Sanitary District office. The little black volume on the left begins with November 1, 1930; the last one on the right is the current 1950 volume. They run consecutively as to years and are uniform as to size and shape. Every day of every year, including Sundays, has entries.

The importance of keeping a diary has been emphasized before in this Log and elsewhere. Once, its entries saved your Logger from arrest, accused of having smashed a police car in a nearby town. The diary proved that on that date and hour the writer was talking to one of his Trustees in the plant office. The accused was another Sperry with similar initials. The diary is the fundamental starting point for the administrative side of record keeping. The daily entries save one from forgetting important items that should be included in the more formal monthly report made to the Board of Trustees. Thus, the preparation of Board Meeting reports starts with a careful combing of the current month in the diary. The diary generally records the various activities of each day by both the superintendent and men, visitors, conferences, contacts with Trustees, decisions with Trustees by phone, moneys received, unusual occurrences, and complaints. Diary keeping is, therefore, one of the important responsible operation functions.

April 3—The day operator just reported his inability to run the cross flights in the west tank of our secondary settling tanks. The usual careful back-flushing with a 100-g.p.m. house pump did not help. A heavy wrench with pipe, applied to the drive shaft, failed to budge the system. We were forced to pump the tank down with our portable gasoline rig, only to find a short piece of 2×6 wedged in the chain. From whence it came no one could tell. This process gets monotonous. Twice before it was a fisherman's bait can blocking the suction bell. Sometimes it is an accumulation of snail shells and sand from the filters. Oddly enough, it is always the west side that is in trouble. We have never pumped the east side for similar cause, yet it is nearest the river, where fishermen often pass.

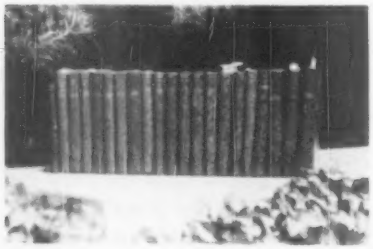

FIGURE 1.—Evidence concerning 21 years of plant affairs at Aurora, Ill.

April 5—Perhaps it was fortunate that the 2×6 did give us trouble in the secondary tank. While the tank was pumped down one of the men noticed that a pin in the long flight chain was almost out of its bearing in the link. Investigation revealed that about 50 pins in the west chain of the west tank needed immediate replacing. The east chain was uninjured. The west chain appeared to ride one of the sprocket wheels. This caused a side pressure on the link that was gradually wearing away the rivet end of the pin. Some careful measurements of the distances between the centers of the sprocket wheels showed that one of the sprockets was out of line. A pair of hydraulic jacks loaned by the friendly local utility pushed the sprocket back into true alignment. Further examination of the chain condition indicated that by reversing the sprockets and turning the chain this summer, several more years of wear would result. Turning the chain is easy. We do not like the job of turning the sprockets, but chain experts tell us that this is a "must."

May 1—Never forget that once in 100 years something catastrophic happens with weather, either as to rainfall or

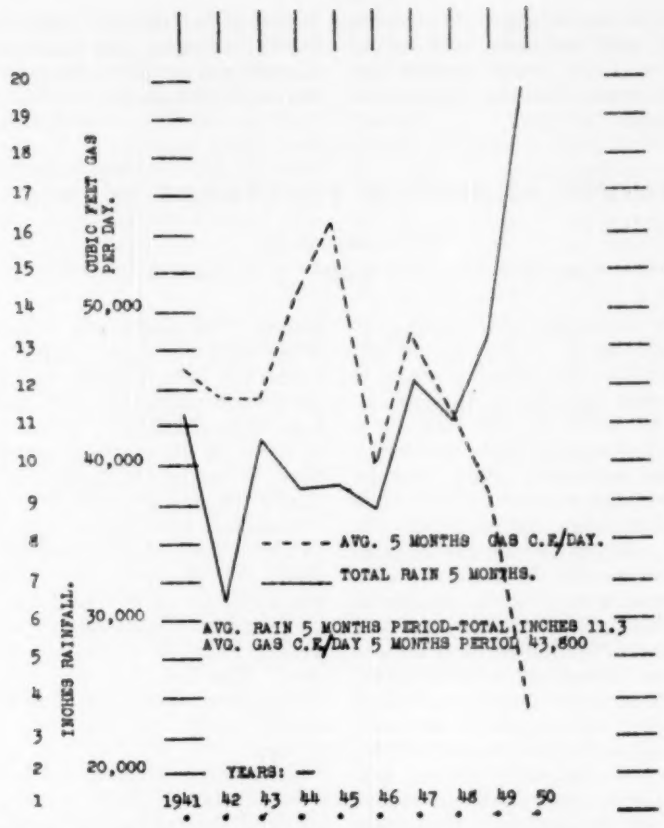

FIGURE 2.—Relation of total rainfall to average gas production at Aurora, Ill., during 5-month period (Dec. 1 to May 1) from 1941 to 1950.

temperature. Witness the New York City water shortage due to the lowest rainfall since 1882 and the Red River flood problem at Winnipeg, Canada. The total gas produced at the Aurora plant on January 10 was 6,400 cu.ft.; on April 4, 8,700 cu. ft. This was the lowest ever recorded in twenty years. The raw sewage B.O.D. averaged 70 p.p.m. in January, and 42 p.p.m. in April. Suspended raw sewage solids for the two months averaged 131 and 142 p.p.m., respectively. The annual average received B.O.D. is about 125 p.p.m., with 200 p.p.m. of suspended solids. Our filters and secondary tanks were taken out of service on Dec. 28, 1949, and not cut in again until May 17, partly due to high flows in the river and low gas. An oil burner was installed on January 12 to keep the office warm. Not for 20 years had there been this need. The sewage was lean and the volume large; digester temperatures dropped as low as 72° F. For a while some toxic waste discharge was suspected until we attended an operators' conference and learned that the condition was general. As one superintendent put it, "What can you expect when raw sewage B.O.D.'s range in the neighbor-

hood of 40 and 50 p.p.m.?" He was plagued with the same troubles we encountered—too much surface and leakage water. All this suggested a review of our records, which resulted in the interesting and completely explanatory story told in the accompanying curve (Figure 2).

SAFETY AT SEWAGE TREATMENT PLANTS*

By Gordon E. Mau

Sanitary Engineer, State Board of Health, Lawrence, Kans.

Safety measures are intended to guard against a combination of unusual events. To bring a series of such events together so that an accident can occur requires time for a suitable environment to be developed, and three additional factors; namely, the scene (designed by engineers), the active component (derived from the sewage), and the person who supplies the action causing the accident. It is quite obvious that, where danger is concerned, the person is an important factor in whether an accident occurs. Therefore, educational training along specific operational lines is necessary, so that the requirements of all codes, ordinances, and safety factors will be met, and so that every person will realize that he must think and not be careless in his actions. Occasional disasters are likely to occur, even with the best of precautions. Every plant operator should realize that unless he exercises every precaution he may be the next victim.

Before going further into the need for safety measures, it may be well to consider what kind of accidents have happened in the past, and against which safety measures are now provided as a matter of routine.

Obvious Safety Measures

A fence around a sewage treatment plant is a very worthwhile safety feature. For some reason, particularly where there is a rotary distributor on a trickling filter, children like to visit the sewage treatment plant and have a merry-go-round ride. They also like to show off by walking around the edges of basins, etc., and as a result disaster frequently occurs.

Some four or five years ago a young boy in a nearby state drowned in a sludge storage basin. The plant site was not protected by a fence and nothing prevented the youngster from trespassing when his football entered the area. The ball was found on the sludge scum, which was undisturbed except where the boy had fallen through.

Other safety features are provided in all treatment plants, but are now taken for granted and not usually considered as being there for protective purposes. Some of these are railings around open tanks, gratings over openings in floors, over wet wells, and other locations where a man must occasionally enter a unit. A slip or fall could be disastrous if such features were not provided.

At the treatment plant, manhole covers, gratings, railings, etc., are provided for safety reasons. Therefore, such appurtenances should never be removed for operation and maintenance purposes without being replaced immediately so that the intended purpose will be served. Some safety precaution may be taken whenever any hazard is known. However, all of these safety measures are ineffective

* Presented at 1950 Annual Meeting, Kansas Sewage Works Assn.; Salina, Kans.; Apr. 19–21, 1950.

if one hazard—namely, the hazard of carelessness—is not eliminated. When people become careless, the best of safety measures cannot always protect them from disaster. The municipality is in error if it does not provide all possible safety features. On the other hand, the workman is seriously in error, and is endangering his own well-being, if he does not make use of all the safety facilities provided for his use.

Since separate sludge digestion and gas collection and utilization practices have become common, there have been several serious explosions, resulting in death or serious injuries. Some of these have been due to carelessness, whereas others were caused by lack of safety features in the plant design.

It should be remembered that four factors are necessary before any explosion can occur—the presence of an inflammable gas or vapor, oxygen, a proper mixture of the two, and a source of ignition. Eliminate any of these and there is no possibility of an explosion taking place. The best method for controlling the causative factors and preventing explosive mixtures of gas and air from being formed is to keep the two separated. In separate sludge digestion this is practiced; however, every precaution should be taken in the vicinity of digesters so that the gas cannot become ignited if a leak occurs.

Explosion-Proof Wiring

At one time, very few special precautions were taken in electrical wiring in a plant. Now, consideration would not be given to anything but special explosion-proof wiring, switches, and motors in the vicinity of a digester or gas-holding equipment. Such wiring should also be used in ventilating equipment removing gases likely to contain combustible mixtures.

Until recent years it has not been common practice to provide forced-draft ventilation in those sections of sewage treatment plants located below ground level or where either toxic or combustible gases may form or collect. Such provision is a safeguard for workmen entering a gas-filled chamber and risking exposure to toxic gases or lack of oxygen; also, if operated continuously, it will prevent formation of an explosive mixture. The Kansas State Board of Health now requires that forced-draft ventilation be provided in all such locations. Further, it requires that such ventilating equipment be started automatically whenever the light in these places is turned on.

Examples of Explosions

Some examples of past accidents reported in the literature will serve to indicate how positive ventilation and explosion-proof wiring go together in explosion prevention. In one instance, a separate sludge digester was being pumped prior to making repairs. The pump failed to take suction and an electric light bulb was lowered into the tank to see if the foot valve was covered or obstructed. A serious explosion took place. It is not certain just what occurred, but it is thought that the light bulb dangling on the end of the cord may have caused a spark setting off the explosion.

In 1940, a digester gas explosion occurred at a Michigan sewage treatment plant. This accident was caused by an operator throwing a switch to start the stirring mechanism in the digester. The switch arced, which resulted in an explosive mixture of gases being ignited. To prevent such an occurrence in the future, ventilating equipment was installed to change the air every 2 to 2½ min., and all electrical equipment was replaced with explosion-proof equipment.

In 1944, about $28,000 damage was done by an explosion at another Michigan sewage treatment plant. The exact cause of the accident was not determined, but it was thought that digester gas had leaked into the pump

room and was ignited by sparks from the motors. The pump room was located below ground and did not have a positive means of ventilation. After the repairs were made, explosion-proof electrical equipment and motors, a waste gas burner, and forced-draft ventilation were provided.

In 1948, at an Ohio sewage treatment plant, gasoline fumes were ignited by the arc of a switch as the mechanical blower was started to ventilate the room. The operator in this case was so severely burned that he has been granted total disability by the State.

At one Ohio plant all digester control and light switch equipment was reinstalled with explosion-proof equipment only after an operator was seriously injured by a control house explosion, which occurred when the lights were turned off.

It should not be inferred from this discussion that whenever a person enters a sewer or sewage treatment plant area, he is likely to encounter something detrimental to his well-being. However, as stated, the safety measures are to guard against possible dangerous combinations, even though the probability of such an occurrence is low.

In making sewage treatment plant inspections throughout the state, Board of Health representatives often are asked questions as to why a man feels indisposed, has a lack of appetite, and is not quite up to par for two or three days after having worked in a wet well or in a manhole where there was septic sewage. Such things do not happen only in the smaller communities; in 1949 the newspapers from a large Kansas city carried an item about a workman being pulled from a manhole in an unconscious condition. After applying artificial respiration, he was revived and was confined to his home for several days to recuperate. The cause of this accident was reported to be a lack of oxygen in the manhole. In this particular case, some foresight was shown by not having lost two men instead of having one overcome by "sewer gases." In the past it has been very common that when one man became unconscious in a manhole, another one immediately went down to help him out and he, in turn, was overcome; as a result, two fatalities occurred. Lack of foresight was shown in the particular instance cited in not providing forced-draft ventilation in the vicinity where the men were working.

Ventilation Required

Whenever workmen are performing duties below ground, in a manhole or wet well, forced draft ventilation should be provided. In addition, the men actually performing the duty should have ropes around their bodies, with enough men at the surface of the ground to be able to lift them to safety in the event that they are overcome.

In one plant, a relief operator was overcome by sludge fumes while transferring primary sludge to a hopper before pumping to the digester. He retained consciouness long enough to shut off the sludge valve and thus escaped drowning in raw sludge. Later, an exhaust hood was installed so that this could not occur again. In another plant, a search for a gas leak disclosed that a water leg in the gas system had become dry and had been stuffed with rags—obviously, a very careless procedure.

Within the past two years, a plant operator was found dead in a sewage treatment plant meter pit. The operator had entered the pit in his routine meter reading. When he did not return after an hour or so, his fellow workers began a search and found him in the meter pit, where an oxygen deficiency existed.

During the past two or three years the lives of four South Texas sewage works men were lost due to accidents within the short space of 25 days. In the first case, the operator had entered the wet well, and apparently been over-

come by gas. Upon seeing him in this condition, his assistant also entered the well and he, too, was overcome. Two or three hours later, both men were found suffocated in the wet well. In the second accident, men were working in the bottom of a drain well, which received citrus wastes. Of the three men overcome by gas, two did not survive.

Natural ventilation is eliminated where sewers are flowing under a head, and gases from decomposition or industrial wastes may collect in a manhole. Maintenance should be carried out with every precaution when such a condition is present.

Testing equipment should be available, wherever adequate ventilation is not provided, so that it may be determined whether any explosive or toxic gases are present and whether oxygen is present in sufficient amounts. A common gas mask is worthless if the atmosphere shows an oxygen deficiency. Where temporary ventilation is needed, it may be provided by an ensilage cutter, or some such similar piece of equipment. The cost of renting equipment of this type for a day or two would not be prohibitive, and it would provide a safeguard for workers. Larger cities may find it profitable to provide their own ventilating equipment.

Hazards from Industrial Wastes

One of the most common, and serious, hazards in the sewage system is illegal discharge of industrial wastes. Cleaning fluid, small amounts of gasoline used for cleaning or other purposes, and waste oil often are discharged to the sewer system by irresponsible persons. It should always be remembered that gases and vapors found in sewer lines will not ignite unless the proper percentage is present with oxygen so that an explosive or combustible mixture is formed. Under proper conditions, only a spark is necessary to have a disastrous occurrence. Some people make a practice of throwing a lighted newspaper into a manhole to see if oxygen is present. Such a practice may result not only in blowing up a sewer, but also in serious personal injury. All municipalities should make a regular practice of inspecting sewer systems to see if sedimentation is occurring in any sections of the sewer, to see if any septic conditions are developing, and to determine where illegal industrial wastes have their origin. They should adopt and rigidly enforce controls over any illegal practices that may endanger the sewers or persons working in them.

In 1949, sewer-wrecking explosions occurred in Ohio and Indiana. One was thought to have been caused by ignition of wasted gasoline; the other, by a spark from a short in an underground cable igniting an accumulation of gases.

Inadequate inspections may fail to disclose that gas from leaks in nearby pipelines is entering the sewers and forming an explosive mixture. Recently, a contractor in Kansas was seriously burned when he entered a sewer, which did not have any sewage in it. A gas leak nearby resulted in an explosive mixture being present in the sewer; the mixture was ignited by his lighted cigarette. Hazards have been caused by gasoline and fuel storage tanks being located too close to sewers, so that leakage from the tanks gained entrance to the sewer.

In 1947, in Illinois, a sewage treatment plant operator carelessly tossed a match into the comminutor chamber at the treatment plant. In the resulting fire the operator luckily escaped with only singed hair and eyelashes. It was found that gas from two leaks in propane gas installations was entering the sewer. Such gas, as is common with many sewer gases, is heavier than air; therefore, it continued to move downstream in the sewer until it reached the plant.

Gas Safety Devices

If certain safety precautions are not taken, all boilers at sewage treatment works present a very serious problem. Some protective devices are: an adequate pressure release system, a water reservoir in the circulating system so that there is an adequate water supply, automatic control equipment so that maximum safe temperatures and pressures are not exceeded, and adequate ventilation in the room. Also, it is desirable to have all explosion-proof electrical wiring in the vicinity of gas equipment so that a potential explosion or fire is arrested if gas escapes into the room. Another essential feature is the provision of flame traps on all supply lines to various gas-burning equipment. The flame trap protects the gas collection and distribution system against entrance of flames from points where the gas is used as fuel. To insure that pressure regulating gages are serving their intended purpose, frequent checks should be made to see that they are properly adjusted.

In sludge digestion tank maintenance it should be remembered that severe burns may result when iron sulfide deposits are exposed to the atmosphere. Iron sulfide deposits are formed by hydrogen sulfide attacking steel. Not only may parts of the body which come in contact with this product be burned, but the substance also has been known to have sufficient spontaneous heat to cause ignition, resulting in a fire or explosion.

Other safety features include good housekeeping. This means keeping all grease, sludge, and any other slippery substance off floors, walkways, etc. Hoses, tools, and maintenance materials should not be left scattered around the plant site.

Water hoses supplied from a municipal system should not be left submerged, because such practice forms a cross connection of the worst type and endangers the public water supply.

Additional precautions which should not be overlooked among sewage system workers is that thorough washing of the hands is necessary. They should be continually reminded that sewage may carry many pathogenic disease organisms; therefore, carelessness on their part may result in illness. All workers should have typhoid immunization, and the shots should be kept up to date. It is up to the city governing body to see that any employee exposed to undue danger is as fully protected as possible. Superficial cuts must not be neglected. To care for such injuries, workers should be provided with adequate first aid equipment.

The foremost thought in the mind of every sewage treatment plant operator should be "stop and think," so that accidents may be avoided.

IMPORTANCE OF GOOD HOUSE CONNECTIONS *

By D. C. Wesche

City Engineer, Manhattan, Kansas

Between each building and public sewer or main is an important link, the house connection. In a sense, the house connection is a part of both the house plumbing system and the public sewer system. A break or fault in this short system usually brings trouble to both the property owner and the municipality.

* Presented at 1950 Annual Meeting, Kansas Sewage Works Assn.; Salina, Kans.; Apr. 19–21, 1950.

The Manhattan (Kans.) Plumbing Ordinance, although by no means a model, is believed to cover most of the important factors needed in the construction of a good serviceable connection to the city sewer mains. Four very important points concerning the building of this connection are:

1. The types of pipe or tile permitted. The Manhattan ordinance permits use of 6-in. vitrified clay pipe and 4-in. extra heavy cast-iron soil pipe.

2. Excavation of the trench from the building to the sewer main. The use of a backhoe or other mechanical device is becoming more popular in the excavation of the trench. However, the use of mechanical trenchers is not recommended, because the operator usually is not careful enough about the grade and generally fails to go over the job thoroughly before starting. Thus, many times, gas lines, water lines, sewers, and other buried utilities are either damaged or broken in the process. If the operator is careful in his grading and stays from 6 to 8 in. above grade line, the last few inches may be excavated by hand, thus assuring a solid and firm base under the entire length of the sewer.

3. The connection of the house lateral to the city main. This is perhaps the most important part of the entire project. A poor connection will jeopardize the operation of the house service, as well as that of the main or lateral of the municipality. It depends on this connection whether or not the property owner has a good working plumbing system, and also whether or not the municipality is liable to have trouble with stoppage in its mains, affecting not only the service with the poor connection, but also many other buildings connected to the same main.

The connection to the sewer main can be made in two ways—by tapping the main and using a factory-made saddle connector, or by connecting to Y's placed in the main during construction for this purpose. In Manhattan, the plumber or drainlayer has been permitted to tap the sewer and install the saddle connector, as stated previously. However, this is not the best policy for a trouble-free plumbing or sewer system and it is planned in the future to install Y's in all new sewer main construction and require all property owners to connect to the main by this method. This connection, as well as the laying of the sewer, must be made by a licensed plumber or drainlayer and the work inspected by the building inspector before being covered.

Many times investigation of a stoppage in the sewer main reveals the trouble to be due to a poor connection. Some of the jointing compound, mortar, or other materials may have worked through the joint and set up in the flow line, making it rough and causing solids to build a dam. Also, if the plumber or drainlayer is not patient and careful when tapping the sewer, prior to inserting the saddle connector, broken pieces of tile in the flow line, or a completely cracked or broken section of tile, may result. Therefore, the use of Y's for house connections is definitely to be preferred as leading to many more trouble-free days or months of sewer main operation.

4. The grade on which the house sewer is laid. It is essential for good operation of the plumbing system that this factor be stressed. The sewer preferably should be laid on a grade of ¼ in. per ft. (or 2 ft. per 100 ft.), with an absolute minimum of ⅛ in. per ft. When it is necessary to use the minimum grade, construction, alignment, and grading are checked even more closely than usual.

If the four points discussed are strictly adhered to and the construction is correctly followed, a trouble-free house sewer connection will result. It is well to remember that there is no extra cost for careful workmanship, but the cost of carelessness is high.

TIPS AND QUIPS

"A" for Effort

Closing date (June 1) for the Federation's 1950 William D. Hatfield Award competition brings several last minute entries, indicating that more and more operators are determined to have a try at winning one of the coveted awards. Reports have been received from plants of all three award classifications as to population served, and are as varied in their concept and execution as the number of entries. Some are beautiful examples of the printer's art, lavishly illustrated, and obviously the result of cooperative effort by sizeable staffs. At the other extreme are neat and compact "one-man" reports from some of the smaller plants, with one (59 pages) even handwritten and hand-titled.

The operator submitting this particular report is to be commended for his attitude in entering the competition despite the handicap of not having stenographic facilities available to him. Regardless of the final selections made by the Operation Reports Committee, he certainly deserves an "A" for effort.

Street Inlets and Storm Sewers

The Institute for Cooperative Research, The Johns Hopkins University, Baltimore, Md., has tackled that exasperating problem of urban life—the clogged and faulty storm-water inlet and storm sewer. J. C. Geyer, of the University's Department of Sanitary Engineering, is heading up the study for the Institute, which embraces all the University's governmental and industrial research contracts.

The project calls for the development of improved techniques for the design of inlets and storm sewers and is sponsored jointly by the Baltimore Municipal Department of Public Works, the Baltimore County Metropolitan District, and the Maryland State Roads Commission. Results are expected to assist in efforts to reduce the annoyance and hazard of flooded streets and highways with minimum expenditure of public money, and will be of interest to other cities and states across the nation. Millions are spent annually by city, state, and town officials for storm inlets and sewers, and an error in design, either under-design or over-design, represents a considerable sum of money.

One of the first steps has been to take the "street" indoors, where Dr. Geyer, his team of scientific researchers, and the Storm Drainage Research Committee, representing the sponsoring governmental agencies, are testing all types of curb and gutter inlets. This hydraulic street model has been constructed with both the gutter slope and cross street slope adjustable, and the water rushes down the 20-ft. wooden platform where model inlets may be readily installed for testing under variable discharges, slopes, deflectors, depressions, and other factors. Concurrent with laboratory study, field tests of inlets are being made to check the model results and to study problems, such as rainfall distribution and intensity, that cannot be reproduced in the laboratory.

Recaps for Flight Shoes

In an effort to reduce material and installation costs on replacement of worn settling tank flight wearing shoes, N. Herda, utilities superintendent of Ypsilanti Township, Mich., has devised a simple angle-iron recap to fasten over the original wearing shoe.

As reported in the May, 1950, issue of *Michigan Sewage Works Bulletin*, the recap shoes were made of 6-in. lengths of 2½- by 3½-in. standard angle iron, punched or drilled on the 3½-in. side to accommodate the fasten-

ing bolts. Installation of the new wearing surfaces on 13 flights in each of four primary settling tanks did not require the usual dewatering of the tanks; it was only necessary to remove the top two bolts from each shoe and secure the new angle with the same bolts. Time to make the installation in the four tanks totaled about 8 hr. Cost of materials and labor for renewing the wearing shoe life in the four tanks was $76, as compared with a cost of more than $200 for replacing the shoes during 1946.

Simple Odor Control

When F. J. Cramer, superintendent of the sewage treatment plant at Greece, N. Y., received some complaints that an odor from the plant could be detected, he solved the problem effectively by removing the psychological cause of the complaints. The remedy consisted not of deodorizing or masking the already inoffensive atmosphere of the plant, but of simply removing from the entrance to the plant drive a large sign reading "Town of Greece Sewage Treatment Plant" and substituting in its place a small sign containing only the words "Town of Greece"!

Supercharged Dual-Fuel Engines

Five supercharged dual-fuel engines, totaling 2,925 h.p., are being installed in the Bay Park activated sludge plant of the new $7,500,000 Nassau County (N. Y.) sewage system. It is claimed that this is the first such installation in the Eastern U. S. to be predominantly fueled with sludge gas.

Two of the engines will drive generators, which will supply electric energy for the treatment plant's requirements. Two others will drive rotary, positive displacement blowers, each supplying 8,500 c.f.m. of free air at 8 p.s.i. for distribution in the aeration tanks. The fifth, and largest, unit is a combination drive to both a 500-kw. generator and a 16,000-c.f.m. blower. In the large unit, the engine is directly connected to the generator; the blower is connected by means of a special coupling, permitting it to be disconnected when the unit is used for power generation. Space is provided for future installation of another combined unit of the same type.

In full operation, the Bay Park plant will treat 27 m.g.d., producing about 170,000 cu. ft. per day of sludge gas having a heating value of 550 to 600 B.t.u. per cu. ft. The engine installation is designed to allow maximum power for a given space allotment, as it utilizes the highest thermal efficiency of any heat engine arrangement currently available.

Practical Public Relations

One never knows from which direction good public relations may one day return home, bringing along the proverbial "bacon." A good case in point is the experience of James Ingalls, a participant in a panel discussion on "Digester Operating Problems" at the 1950 Annual Meeting of the Pacific Northwest Sewage Works Association, held in Tacoma, Wash., May 10–11. Besides being superintendent of the sewage treatment plant at Coeur d'Alene, Idaho, Mr. Ingalls, as a result of his practical approach to the matter, is also a member of the Idaho State Legislature!

The Moon and Sewage Disposal

Through countless ages the moon has been credited with mystical effect on the course of innumerable earthly affairs. Some, such as the ebb and flow of the ocean tides, are scientifically demonstrable; others, such as the rise and fall in popularity of "Lovers' Lanes," are subject to sentimental

interference patterns. Still others have been proven to be only figments of vivid imaginations, or superstitious hand-me-downs from our cave-dwelling ancestors.

Now, however, a new angle has been added—the moon may have an influence on certain types of sewage treatment!

The suggestion is contained in a paper presented at the May, 1950, meeting of the Midland, North Eastern and North Western Branches, Institute of Sewage Purification. The authors, A. R. Stone and W. E. Abbott, manager and chemist, respectively, Sewage Disposal Department, Nottingham, England, after describing the irrigation methods practiced at the Nottingham treatment works and the experiments being carried out in connection therewith, go on to say:

"The details of the sewage irrigation are attended to by workmen whose views, often the result of long experience, generally command our respect. It is, therefore, perhaps worth recording that more than one has expressed the opinion that the irrigation areas are favorably influenced by the moon. There is no inherent reason, if photosynthesis is normally a favorable factor, why the continuation of some degree of light throughout the night should not have a favorable effect. The samples necessary to decide whether the suggestion is true cannot be taken and therefore we cannot support the statements."

It may well be that in the future, logs of plants utilizing irrigation may even contain such moon-struck notations as:

Algae active under bright full moon,
Suppose clouds'll end it all too soon.

On the other hand, judging from the comments heard about the pea-soup fogs of England, one is tempted to ask: "What moon?"

Proceedings of Member Associations

NEW JERSEY SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

35th Annual Meeting

Trenton, New Jersey, March 22–24, 1950

The 35th Annual Meeting of the New Jersey Sewage Works Association was held at the Stacy-Trent Hotel, Trenton, N. J., March 22–24, 1950. Total registration at the meeting was 351, only slightly less than the all-time record set in 1949. As usual, the Association's famous Speechless Dinner and Entertainment, sponsored by the Water and Sewage Works Manufacturers' Association, proved one of the popular highlights of the meeting.

Papers presented at the industrial wastes session on the afternoon of March 22 were:

"Reduction in Load on Sewage Treatment Plants by Fiber Recovery," by N. L. Nemerow, research assistant, Department of Sanitation, Rutgers University.

"The Treatment of Penicillin Waste," by D. L. Muss, sanitary engineer, Heyden Chemical Corp.

"Breaking in an Industrial Waste Treatment Plant," by Harold Orford, research assistant, Department of Sanitation, Rutgers University.

The morning session on March 23 was predominantly devoted to new equipment and process descriptions and included the following papers:

"New Daytona Beach Process and Aero-Accelator," by F. A. Eidness, Infilco, Inc.

"New Developments in Aeration Equipment," by J. D. Walker and J. R. Sperry, Walker Process Equipment, Inc.

"Diffused Air in Sewage Treatment," by S. E. Kappe and J. B. Neighbor, Chicago Pump Co.

"Improvement at the Digester," by A. R. Reiners, The Cloroben Corp.

"The Mechanism of Oxidative Sewage Purification, Its Measurement and Interpretation," by W. W. Eckenfelder, Jr., and John W. Hood, consulting sanitary chemist and superintendent, respectively, sewage treatment plant, Ridgewood, N. J.

After a report on Federation affairs by R. E. Fuhrman, Federation vice-president and superintendent of the District of Columbia sewage treatment plant, the March 23 afternoon session heard papers on:

"Sewage Disposal in an Environmental Sanitation Program," by A. H. Fletcher, director, Bureau of Environmental Sanitation, New Jersey State Department of Health.

"The Viewpoint of Public Officials on the Environmental Sanitation Program," by G. H. Cullis, chairman, Essex and Union County Joint Meeting Commission.

"The Role of a Sanitary Engineer in the Environmental Sanitation Program," by T. F. Bowe, consulting engineer, New York, N. Y.

The bulk of the morning of March 24 was devoted to an Operators' Symposium, which included discussions of such subjects as sedimentation, digestion, general maintenance, and labor relations.

At the business meeting preceding the symposium, the Association adopted

constitutional amendments changing the name to the New Jersey Sewage and Industrial Wastes Association. Officers elected for 1950–51 were:

President: John Struss, Wildwood.
1st Vice-President: Sol Seid, New Brunswick.
2nd Vice-President: Paul Molitor, Jr., Rutherford.
Secretary-Treasurer: M. S. Kachorsky, Manville.

M. S. KACHORSKY,
Secretary-Treasurer

MONTANA SEWAGE WORKS ASSOCIATION

Sixth Annual Meeting

Missoula, Montana, April 20, 1950

A record-breaking registration of 82, or 21 more than the previous highest registration (established in 1949), marked the tenor of the Sixth Annual Meeting of the Montana Sewage Works Association held at the Florence Hotel, Missoula, Montana, April 20, 1950.

The one-day technical program included major committee reports on "Standard Practices in the Design, Construction, and Maintenance of Sanitary Sewer Systems in Montana" and "The School for Water and Sewage Works Operators and Managers," as well as the following papers:

"Garbage Collection and Disposal in Montana," by H. E. Garber, sanitary engineer, Montana State Board of Health, Helena.

"Water Pollution Control," by L. F. Warrick, chief, Technical Services Branch, Division of Water Pollution Control, U.S.P.H.S.

"Recent Developments in the Sewage Works Field," by G. J. Schroepfer, professor of sanitary engineering, University of Minnesota.

These were followed by a roundtable discussion of operation problems, led by J. H. Morrison, consulting engineer, Helena.

At the business meeting, H. B. Foote, director, State Board of Health, Helena, was nominated to receive the Federation's Arthur Sidney Bedell Award.

Officers elected for 1950–51 were:

Chairman: Kurt Wiel, Miles City.
Vice-Chairman: Rodney Preator, Helena.
FSWA Director: Earl Eby, Helena.
Secretary-Treasurer: H. B. Foote, Helena.

H. B. FOOTE,
Secretary-Treasurer

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Pennsylvania Sewage and Industrial Wastes Association	Pennsylvania State College, State College, Pa.	Aug. 23–25, 1950
Canadian Institute on Sewage and Sanitation	Bigwin Inn, Lake of Bay, Ont.	Sept. 11–13, 1950
West Virginia Sewage and Industrial Wastes Association	Hotel Pritchard, Huntington, W. Va.	Sept. 14–15, 1950
Iowa Sewage Works Association	Hotel Blackhawk, Davenport, Ia.	Sept. 19–21, 1950
Georgia Water and Sewage Association	Ga. Institute of Technology, Atlanta, Ga.	Sept. 20–22, 1950
Rocky Mountain Sewage Works Association	La Fonda Hotel, Santa Fe, N. Mex.	Sept. 27–29, 1950
New England Sewage Works Association	Hotel Stratfield Bridgeport, Conn.	Sept. 28, 1950
South Dakota Water and Sewage Works Conference	Aberdeen, S. Dak.	Sept. 28–29, 1950
Missouri Water and Sewerage Conference	Sheraton Hotel, St. Louis, Mo.	Oct. 1–3, 1950
Federation of Sewage Works Associations	**Hotel Statler Washington, D. C.**	**Oct. 9–12, 1950**
Kentucky-Tennessee Industrial Wastes and Sewage Works Association	Memphis, Tenn.	Oct. 23–25, 1950
North Carolina Sewage Works Association	Washington-Duke Hotel, Durham, N. C.	Nov. 13–15, 1950

Reviews and Abstracts*

Proceedings of the Fourth Industrial Waste Conference. *Eng. Bull.*, **33**, No. 4 (Extension Series No. 68), Purdue Univ., Lafayette, Ind. (July, 1949).

This bulletin contains the papers presented at the Fourth Industrial Waste Conference, held at Purdue University, Sept. 21–22, 1948, as follows:

Making a Waste Survey for a Large Industry. By W. J. Eldridge. Pp. 7–14.

The need is stressed for effective administration of a pollution control program, for developing waste control methods as new products are developed, and for collecting adequate data in old plants.

An industrial approach which has been successful is described covering such points as: employment of competent supervisory personnel; use of company records to show relation of raw input and finished output; use of records to show progress; quantities of materials reaching sewers, dumps, and atmosphere; provision of sufficient facilities for laboratory analyses, experimental work, sampling, and flow measurements; publicizing in the plant the results of waste reduction campaigns; studies of applicable treatment methods; use of consultants; cooperation with pollution agencies; and free exchange of information on treatment methods.

Industrial Waste Treatment and Recovery in West Virginia. By Kenneth S. Watson. Pp. 20–31.

The West Virginia Water Commission is engaged in programs of classifying every major stream into quality zones, of educating municipalities in the needs for sewage treatment, and of cooperation with industry in reducing industrial pollution. These programs are discussed and brief reviews given of the tannery, by-products coke, and slaughterhouse problems and their general solutions. No analyses of industrial wastes are given. A table of specifications for streams, including coliform, B.O.D., dissolved oxygen, and chemical requirements, is given along with maps of the resulting water quality zones for two rivers, the Potomac and the Kanawa. Another map shows the status of sewage and industrial waste treatment in the state.

Pulp and Paper Mill Wastes in the Tennessee Valley. By F. W. Kittrell. Pp. 32–39.

The effects of pollution on rivers in the Valley caused by wastes from paper mills of various types is described. The mills, nine in number, produce wastes with an estimated population equivalent of 1,225,000, and at the time the paper was written changes were planned or under way to reduce the load by 40 per cent. These changes are mentioned in a general way with no details. The effect of wastes on one water plant many miles from the source of pollution is shown by a table of analyses, but no other data are included on waste characteristics or the chemical and biological quality of the streams.

The Anaerobic Digestion Rates of Milk Wastes. By R. A. Spaulding. Pp. 40–44.

The results of a series of four tests using 3-l. capacity digestion tanks equipped with stirrers and kept at a constant temperature are given. Synthetic solutions of evap-

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage Works Assns., 325 Illinois Bldg., Champaign, Ill.

orated milk diluted to B.O.D. concentrations ranging from 380 to 3,300 p.p.m. were digested using a 6-day detention period. At this rate there was no souring or building up of the volatile acids. The effluent had a disagreeable odor, which was readily dispelled by a short aeration. B.O.D. reductions of 90 to 99.5 per cent, or an average of 0.0343 lb. per cu. ft. of tank capacity, were reported.

Waste Treatment Facilities of the Belle Center Creamery and Cheese Company. By D. G. Neill. Pp. 45–53.

The creamery processes about 150,000 lb. of milk daily, the principal products being cheese and milk sugar derived from the cheese whey. Waste discharge is to a small stream, and a $65,000 chemical precipitation, rapid filter type plant, designed to handle 40,000 g.p.d. at 6,000 p.p.m. 5-day B.O.D. and operated for one year, did not eliminate pollution.

Before remodeling the treatment plant a study was made of the wastes, following which both the volume and concentrations were reduced. The extent of reduction compared to increased milk intake over a 3-month period is plotted graphically. The plant was remodeled to treat 25,000 g.p.d. at a B.O.D. of 1,200 p.p.m.

The new plant consists of two sumps with preaeration, 25 g.p.m. pumps, two metering and flow regulating boxes, two aerators, three blowers, a clarifier, and a sludge digester. These units and their operation are described in detail.

The results of analytical determinations of the plant operation are not given, but it is stated that the effluent is clear, has an average D.O. of 3 p.p.m., and a B.O.D. of less than 19 p.p.m.

An Aeration Plant for Milk Waste Disposal. By W. Scott Johnson. Pp. 54–62.

The layout and operation of the waste treatment works for the Kraft Foods Company cheese plant at Mansfield, Mo., is described in detail. Wastes are treated in two grease traps in series, and an 8,700-gal. aeration tank, with air provided by a 65-c.f.m. blower. At a measured flow of 12,000 g.p.d., 7.8 cu. ft. of air was provided per gallon of waste. The entire flow occurs during approximately 12 hr. and effluent is recirculated throughout the remaining period.

The plant was designed to supply sufficient air in fine bubbles to maintain aerobic conditions, but not to produce an activated sludge. A 24-hr. detention was planned, but at the time studies were made, detention was only 17 hrs. At this loading only one 24-hr. test was made, and it showed an 18 per cent B.O.D. reduction when the raw B.O.D. was 1,268 p.p.m.

Industrial Sanitary Engineering in Dairy Plant Management. By M. D. Sanders. Pp. 63–66.

The article points out in general terms the ways in which sanitary engineers can be of value to the milk industry in working with management to reduce losses and plan treatment, and how cooperation with the supervisory personnel at the local disposal plant may result in solutions of problems, such as whether it is more economical to discharge to the treatment plant or to reduce losses through the use of waste-saving devices.

Two-Stage, High-Rate Trickling Filters for Dairy Waste Treatment. By H. A. Trebler and H. G. Harding. Pp. 67–79.

The opinions and conclusions of several promoters and investigators of one- and two-stage, high-rate, recirculating filters are summarized to show what has been used and recommended for treating domestic wastes. Four milk waste treatment plants, constructed under the supervision of the National Dairy Research Laboratories, are described, and good tables of design and operation data are given. These plants have specially designed circular clarifiers, one half used as a primary and the other half as a final settling tank, with a common sludge hopper. Three of the plants have two-stage filters arranged concentrically in single units with common four-arm distributors. Design capacities range from 20,000 to 100,000 g.p.d., and the filters operate at approximately 15 m.g.a.d.

Results of a number of tests are given, and calculations are made to show efficiencies and filter loadings and removals per cubic yard of filter media. The average B.O.D. removed per cubic yard of media for each test ranged from 0.84 to 1.69 lb., with average plant efficiencies ranging from 86.2 to 95.8 per cent.

Composting Spent Hops. By Charles F. Niles, Jr. Pp. 80–93.

Spent composted hops have been used as a fertilizer and soil conditioner. Methods of composting were studied, using two composts in 4-gal. crocks and two out of doors at the Lafayette, Ind., brewery. Those out of doors were 18 ft. in circumference and 4 and 6 ft. deep. Horse manure was used in three trials and various "fortifiers" in all.

Three to four months' composting showed 55 to 70 per cent solids reduction and approximately 50 per cent nitrogen reduction. No manure was added to one outdoor compost and it was concluded that none was necessary. Air penetrated only approximately 18 in. into the pile and appeared to be necessary for satisfactory decomposition. No odor nuisance resulted from any of the composts, even when the material in one case was turned over to expose new surfaces.

Others reporting on the fertilizing values of composted hops differ in their opinions and no studies were made here to determine the amount of nutrients available.

Anaerobic Treatment of Distillery Wastes (Pilot Plant Studies). By Alex B. Davidson and James F. Banks. Pp. 94–105.

The paper opens with a concise description of the separation and drying of both thick and thin spent mash, which by-products are not included in distillery wastes. The composition of average wastes is given.

Five groups of digestion experiments were made, the first three on a batch basis using 4-l. laboratory bottles, and the last two in a 17-l. jar. These units were equipped with agitators and appurtenances for feeding and withdrawing wastes and for removing gas.

In the batch studies after the established digestion period elapsed, the digester contents were settled for 1 hr., clear supernatant was withdrawn, and fresh raw wastes were added to refill to the original level. Supernatant was aerated 30 min. and settled 1 hr. Five-day B.O.D. was determined for the raw, the original supernatant, and the aerated supernatant. The volume and time spacing of withdrawal was arranged to give detentions of 48, 67 to 73, and 22 to 35 hr. Graphs are included showing gas collected, B.O.D. of the raw wastes, and per cent B.O.D. reduction for the settled digester effluent before and after aeration. Results for a 48-hr. digestion period showed an average over-all B.O.D. reduction of 98 per cent.

In the continuous feed studies, 30- and 22-hr. detention periods were used, with an over-all B.O.D. reduction of 93 per cent obtained for the 30-hr. period. At the shorter period the effluent contained a considerable amount of sludge. Operational difficulties for the smaller units make larger-scale work desirable.

The Treatment of Compressed Yeast Effluents. By E. H. Trubnick and W. Rudolfs. Pp. 109–121.

This material is covered in a series of six articles in *Sewage Works Journal* ending 21, 6, 1028.

Research in the Disposal of Distillery Wastes. By E. C. Pattee. Pp. 122–128.

A summation of disposal processes is given for wastes from whisky and brandy distilleries. The manner of separating solids from liquids is determined by an over-all cost balance, and a table showing clarification methods and efficiencies is given for grain distillery slop.

In whisky processing the use of screens, presses, evaporators, rotary dryers, spray dryers, filters, and centrifuges is discussed. Processing depends on the by-products made, such as high-vitamin feeds, proteins, chemicals, and yeast. Although complete reclamation of slops is desirable, the need and use of biological treatment for wash waters and evaporator effluent is mentioned.

Brandy slops are similar to distillery slops, with the addition of wine tank settlings and grape seeds and skins. All concentrated wastes are mixed and handled similarly to those of a grain distillery, except that the concentrated syrups from the evaporators are cooled and the cream of tartar that crystalizes is removed by centrifuging. Digestion of brandy slops has been investigated with poor results.

The corrosion due to the use of high-velocity evaporators and the possible return of low-velocity units, or the use of high-cost alloy construction, is briefly discussed.

Design of a Grease-Recovery Plant for a Meat Packer. By Arthur H. Beard, Jr. Pp. 129–140.

A review of data on weights of animals slaughtered, volumes of wastes, and quantities of B.O.D., suspended solids, and grease in the waste, obtained by several prominent investigators and the author, is given. There is considerable variation in the data, that for grease showing from 1.3 to 7 lb. per 1,000 lb. of live weight.

There are two types of grease: (1) fats resulting from slaughtering and dressing, and (2) fats or oils from the cooking, curing, and rendering processes. Separate facilities are recommended for recovery of each. Slaughtering wastes separate readily and should be removed before being combined with process fats. The types of units required and sequence of their use are discussed.

Particular attention is given to such factors as collection of various grades of grease, rapid handling of the accumulated grease to prevent acid conditions and resulting deterioration, and the exclusion from the separators of wastes that would reduce the degree of recovery and quality of the grease.

On the basis of average waste volumes and grease and solids data, a design is outlined for a two-stage recovery system, using aero-flocculation, for a large packing plant processing cattle and hogs. The basis of design and the reason for each step in the planning is given, and an estimate of costs, value of the recovered material, and profit are included.

Research in Anaerobic Treatment of Canning-Plant Wastes. By O. H. Hert. Pp. 141–149.

Laboratory studies by graduate students on separate digestion tests of synthetic tomato, pumpkin, and pea wastes are described and tables showing results are included. Gallon glass jugs were used for test runs covering 6 to 14 days.

Various loadings were used, ranging from 0.863 to 10.4 lb. of B.O.D. per 1,000 cu. ft. of digester capacity for tomato wastes, and 5.75 to 29.5 lb. B.O.D. per 1,000 cu. ft. for pumpkin wastes. Graphs are given showing the relation between the pounds of B.O.D. added to the digesters and that removed. Tests were incomplete for pea wastes.

Using data obtained, examples are given showing how to compute the capacity of a lagoon required to reduce the B.O.D. to any figure.

Anaerobic Digestion of Tomato and Pumpkin Wastes. By R. A. Canham and Don E. Bloodgood. Pp. 150–177.

Mixed domestic sewage and tomato canning wastes were digested in a 3,650-gal. tank equipped with stirring paddles. Three short tests were made (digestion periods of 10, 7.5, and 5 days) with wastes introduced over periods of from 2.25 to 8 hr.; one was made with a continuous loading at the rate of 0.86 g.p.m., or a digestion period of 2.9 days. Tables of daily operating and analytical results show the best B.O.D. removal, averaging 5.17 lb. per 1,000 cu. ft. of digester capacity per day, with the loading averaging 7.75 lb. per 1,000 cu. ft. and a digestion period of 7.5 days.

Supernatant from a mixed domestic sewage and synthetic pumpkin waste was digested for 12 days with a batch feed every other day at the rate of 40-days detention. In starting, the tank was filled with a weak waste; the dilution affected the laboratory results. Calculations showed B.O.D. removal to range from 0.53 to 1.74 lb. per cu. ft. of digester capacity daily.

W. A. Hasfurther

Treatment of Paper Mill Wastes in Biochemical Oxidation Ponds. By C. C. Porter and F. W. Bishop. *Ind. and Eng. Chem.*, **42**, 1, 102 (Jan., 1950).

At a Texas paper mill using pine as raw material for manufacturing ground wood unbleached and bleached kraft pulp, the plant wastes discharge into an intermittent stream, which flows several miles to a river having a very low flow during the summer months. Laboratory work showed that chemical treatment of the wastes would be impracticable, and inasmuch as the topography of the plant site and surroundings permitted the construction of impounding reservoirs it was decided to study the effect of storage on the wastes. Storage tests were performed under aerobic and anaerobic conditions.

Fairly large-scale field studies were also conducted. The latter studies showed that the rate of B.O.D. reduction after 10

days of storage was very slow as compared to that of the first 10 days. Based on laboratory and field studies, two large earthen reservoirs, each of 50-acre extent, were constructed. The total volume of 250 acre-ft. provided a detention time of about 13 days at a 12 c.f.s. waste flow. A typical pattern of B.O.D. reduction through the ponds was: mill outfall, 200 p.p.m.; effluent of first pond, 160 p.p.m.; effluent of second pond, 120 p.p.m.; second pond effluent at river, 90 p.p.m. With the reservoirs in operation and a river flow of 400 c.f.s., the dissolved oxygen at the sag point in the river was 4.1 p.p.m. With a dilution ratio of 4.5 to 1 the dissolved oxygen fell to 3.4 p.p.m. During the months of August and September, the average temperature of the impounded waste was 89°F. and the B.O.D. pattern was: mill effluent, 200 p.p.m.; first pond effluent, 120 p.p.m.; second pond effluent, 90 p.p.m.; effluent at river, 35 p.p.m. Thus, B.O.D. decreased 55 p.p.m. in flowing through 10 mi. of stream bed between the second pond and the river. Blue-green algae growths were noted along this stream bed. The pH of the waste throughout the disposal system varied from 7.8 to 8.6. Normally 4,500 lb. per day of sulfate were included in the mill effluent. The sulfate concentration was reduced to zero in the second pond effluent. This is believed to result from the action of sulfate reducing bacteria. As impounded kraft mill waste ordinarily has a bad odor, it was difficult to determine that the sulfate reduction was contributing any more.

During 2 years of operation considerable sludge and scum accumulated; it was apparent that eventually sludge removal would pose a serious problem. Following mill expansion in 1948, which placed an additional 10-c.f.s. load on the ponds, a presedimentation pond was built. This was designed for a 16-hr. detention time and constructed so as to permit easy annual cleaning.

The authors conclude that the use of oxidation lagoons should not be presented as a cure-all, but rather as a pollution abatement procedure which may be utilized under favorable conditions.

PAUL D. HANEY

Some Aspects of the Law Relating to Sewers and Drains. By J. A. GALLOWAY. *Surveyor*, **109**, 97 (Feb. 17, 1950); and 113 (Feb. 24, 1950).

This rather long and involved paper states that the general statute law (British) relating to sewers and drains outside London is almost wholly contained in Part II of the Public Health Act, 1936, the Public Health (Drainage of Trade Premises) Act, 1937, and the Rural Water Supplies and Sewerage Act, 1944. The provisions of the Public Health Act, 1875, relating to sewers and drains were repealed by the 1936 Act.

There are three parts to the paper. The introduction, Part I, shows the main changes in the law brought about by the 1936 Act. Part II, on public sewers, deals with the powers and duties of local authorities. Part III, on private sewers and drains, is a discussion of some of the powers of local authorities and private owners regarding sewers and drains other than public sewers.

T. L. HERRICK

Mechanical Filtration of Sewage Effluents. *Surveyor*, **109**, 81 (Feb. 10, 1950).

This article contains discussions of the paper of the same name which appeared in the *Surveyor*, **108**, 581 (Sept. 30, 1949). The abstract of the original paper appears in THIS JOURNAL, **22**, 4,579 (Apr., 1950). The discussions are continued in the February 17 issue of the *Surveyor*.

T. L. HERRICK

Some Notes on the Basis for Design of Low-Rate Trickling Filters Purifying Domestic Sewage. By JOHN H. WALTON. *Jour.*, Inst. San. Eng., **32**, Part 1, 49 (Jan., 1950).

This paper illustrates the use of a chart in the design of low-rate trickling filters, when the dilution available and the stream requirements to be met are given.

T. L. HERRICK

Rivers Pollution Prevention. By G. E. WALKER. *Jour.*, Inst. San. Eng., **49**, Part 1, 36 (Jan., 1950).

A discussion of the pollution control acts in force in England is presented under the following general headings:

A. The common law position.
B. Statutory prohibition of pollution.
   1. Rivers Pollution Prevention Acts, 1876 and 1893.
   2. Salmon and Freshwater Fisheries Act, 1923.
   3. Disadvantages of existing statute law.
C. The Thames catchment area.
   1. Statutory powers—Thames Conservancy Act, 1932.
   2. Constitution of the Conservators.
   3. Administration in connection with river pollution prevention.
D. River Boards Bill.
E. The solution of the problem.
F. Conclusion.

T. L. HERRICK

The Public Sewer. BY SIDNEY F. RICH. *Jour.*, Inst. San. Eng., **49**, Part 1, 12 (Jan., 1950).

This is "an examination of the fundamentals in sanitary law and administration" in English practice. The meaning of the terms "sewers" and "drains" is discussed. Legal decisions on the use of the terms are cited.

T. L. HERRICK

Sewage Disposal in Sub-Tropical Countries with Special Reference to the Union of South Africa and Mauritius. BY E. J. HAMLIN. *Jour. and Proc.*, Inst. Sew. Purif., Part 3, 235 (1949).

It is pointed out that South African towns are laid out so that the population per acre is as low as four persons. This has affected the cost of sewers and the time taken for sewage to reach the works, which in turn affects the design of the plant. Variations in rainfall are discussed. Extremes range from 17.2 in. per year average for the Union of South Africa to over 100 in. in Mauritius. Over 300 in. have been recorded for one year there.

Regarding the effect of diet on sewage disposal, it is pointed out that in South Africa about 80 per cent of the population lives on a diet composed principally of carbohydrates. It has been found almost impossible to digest the material from bucket removal night soil systems where the majority of the people live on such a diet. However, bucket contents discharged into a sewer and mixed with sewage of a European population are amenable to the digestion process.

There is a good supply of manual labor in South Africa. In some sub-tropical countries the aim is to design sewage works with as little mechanical equipment as possible.

T. L. HERRICK

Investigations on the Dynamics of Aeration. (The Aeration of Clean Water). BY A. HOLROYD and H. B. PARKER. *Jour. and Proc.*, Inst. Sew. Purif., Part 3, 292, (1949).

Experiments carried on with a pilot plant and in the laboratory on the rate of solution of oxygen in water are described. Included are 13 figures and 3 tables.

T. L. HERRICK

Waste Waters from the Manufacture of Cider and their Treatment in Percolating Filters. BY E. E. JONES. *Jour. and Proc.*, Inst. Sew. Purif., Part 2, 212 (1949).

Studies were made at a cider factory to determine the amount of polluting matter discharged and to find the most suitable conditions for treating a mixture of sewage and waste water in trickling filters. It appeared that most of the pollution came from the bottling and bottle washing department and from the washing of filter cloths. The oxygen demand of a mixture of all waste waters was estimated to be about 1,130 p.p.m.

Experimental work included tests with 9-in. diameter filters containing 3.75 ft. of coke media graded $\frac{3}{4}$ in. to $1\frac{1}{4}$ in. After all filters were matured by applications of settled domestic sewage, they were used with various methods of operation. Filter 1, used as control, was fed settled domestic sewage by single filtration. The others were fed a mixture consisting of one volume of settled sewage and one of diluted cider. Filter 2 was used to treat the mixture by single filtration. Filters 3 and 4 were used as recirculation units, returning two and one volumes, respectively. Units 5 and 6 were used as alternating double filtration units. The mixtures of settled sewage and diluted cider were made up to approach the strength of sewage at the town outfall (about 800 p.p.m. 5-day B.O.D.).

Treatment by single filtration is not recommended for cider wastes, or for a

sewage containing a high proportion of such wastes. Although double filtration produced good effluents, the primary effluent was such that it was not certain that the process would continue to give good effluents on a large scale. It appears that filtration with recirculation would be the most suitable process. With a B.O.D. of 650 p.p.m., filtration with recirculation of an equal volume of effluent gave good results at a rate of 61 g.p.d. per cu. yd.

It appears that if cider wastes were to be treated without admixture with domestic sewage difficulty might be encountered because of the low concentration of nitrogen. Results would probably be greatly improved by the addition of at least 30 p.p.m. of nitrogen.

T. L. Herrick

A Preliminary Study of Ova and Cysts in Cydna Digested Sludge. By E. S. Hogg. *Public Health* (So. Africa), **14**, 1, 27 (Jan., 1950).

The presence of viable ova of intestinal parasites in digested sludge is a moot question. It has been assumed without specific study that drying the sludge was effective in destroying those escaping the digestion process. Recent work done by two or three independent laboratories has shown that this is not the case and that a large percentage of the ova survive the digestion and air drying. A maximum of 5.5 per cent moisture is necessary to ensure the destruction of the ova of ascaris by dehydration.

The nematode ascaris (intestinal round worm), the eggs of which are extremely resistant to drying, were selected for study. Digested sludge containing viable ascaris ova was spread out in layers from 1.5 to 6 in. deep for atmospheric drying. Initial sludge had a moisture content of 84 per cent and of the eggs examined 45 per cent were viable. The moisture content dropped steadily during 5 weeks, but the ratio of viable eggs to those showing no segmentation remained very much the same except in the 1.5-in. thick layer, where the moisture content dropped very rapidly until it was less than 3 per cent at the end of the fifth week. The viable eggs constituted 15 per cent in this case. The sludge layers were allowed to stand for three months. Very few eggs were found in the 1.5-in. layer, with no signs of viability. The 3-in. and 4.5-in. layers, however, showed the presence of viable ascaris ova, although the numbers were very much reduced. It was concluded that sun drying of sludge in thin layers for long periods is effective in destroying ascaris ova.

H. Heukelekian

A Contribution to the Discussion on the Hazard of Ascaris Infection from Sewage. By A. J. Orsenstein. *Public Health* (So. Africa), **14**, 1, 29 (Jan., 1950).

Ascaris lumbricoides is parasitic to pig and man. Development of the egg takes place in the small intestine. Eggs do not normally develop into larvae outside the animal body. The egg is extremely resistant to unfavorable conditions, and in favorable environment may survive for several years. The larvae pierce the mucosa of the intestine, enter the blood stream, and appear in the liver and the lungs, and pass through the trachea, esophagus, and stomach back to the intestine. Ascaris infestation is much more likely in a community where the disposal of night soil is by deposition on the surface. It takes a good deal of infestation to produce parasitation. In infected communities, ascaris ova are found in unfiltered sewage effluents and in digested sludges. Sand filters remove the ova mechanically, without affecting their viability. A plant consisting of sedimentation and trickling filters was investigated. The effluent from the plant is used for watering a golf course. The sludge is only partially digested, air-dried first in underdrained beds, and then in a layer a few inches thick on a concrete platform. It is then composted. It was concluded that there was no serious hazard to the golfer playing on the links and in the use of composted or well-dried sludge on lawns and gardens. Vegetables grown on land irrigated with settled sewage can be handled and eaten with reasonable safety.

H. Heukelekian

Boston Main Drainage Works. Proposed Calf Pasture Sewage Treatment Plant. By John F. Flaherty, Eric Reeves, and Elson T. Killam. *Jour.*, Boston Soc. of Civil Eng., **37**, 1 (Jan., 1950).

This is a symposium of three papers dealing with the sewage treatment problem

involved with the Boston Main Drainage Works. The Boston Main Drainage serves Boston proper, South Boston, and parts of six other communities. It is under the jurisdiction of the City of Boston. Flow is by gravity to the Calf Pasture pumping station, where cage screens are provided. From here the flow is passed through an inverted siphon under Dorchester Bay to Squantum, thence through an outfall sewer to storage basins on Moon Island. Sewage is discharged from the basins on the ebb tide.

A plant has been designed for the Calf Pasture site which will provide screening, sedimentation, chlorination, and digestion. Digester gas will be utilized in dual-fuel engines. The plant is designed for a flow of 85 m.g.d. and a population of 500,000.

Attention is called to other recent papers on the Boston situation. They are "Sewage Treatment and Disposal for Boston," by J. F. Flaherty (THIS JOURNAL, **22**, 3, 277; Mar., 1950); "Maintenance and Operation of Metropolitan Boston Sewers," by T. A. Berrigan (THIS JOURNAL, **22**, 3, 296; Mar., 1950); and "Sewage Works Development in the Massachusetts Metropolitan District," by K. R. Kennison (THIS JOURNAL, **22**, 4, 477; Apr., 1950).

T. L. HERRICK

Radioactive Tracers in Flow Tests. BY RALPH S. ARCHIBALD. *Jour.*, Boston Soc. of Civil Eng., **37**, 49 (Jan., 1950).

This paper is a report of study under a scholarship from the John R. Freeman Fund. It discusses the history of flow measurement by chemical means, and describes laboratory investigations of the salt-velocity method in conduits.

Most of the paper is devoted to studies on the use of radioactive isotopes as tracers for flow tests. The isotope used was Iodine^{131}, which has a half-life of 8.0 days.

T. L. HERRICK

Treatment of Waste Waters from the Pickling of Steel. BY G. E. EDEN AND G. A. TRUESDALE. *Jour.*, Iron and Steel Inst. (Brit.), p. 281 (Mar., 1950).

Experiments of Gehm on the neutralization of dilute solutions of sulfuric acid by application in upward flow to a bed of limestone grit have been extended by the authors to show that the limiting concentration of acid that can be satisfactorily neutralized in this way is dependent on the temperature of the solution. The concentration of sulfuric acid (as H_2SO_4) which could be continuously neutralized without causing inactivation of the particles of limestone ranged from 9,880 p.p.m. at 6° C., to 4,360 p.p.m. at 30.4° C., and at any given temperature appeared to correspond approximately to the concentration of sulfate in a solution of calcium sulfate saturated with respect to the metastable calcium sulfate hemihydrate.

When the method was applied on a laboratory scale to neutralization of solutions similar in composition to waste washing waters from sulfuric pickling of steel, iron in the form of ferrous sulfate did not interfere with neutralization of free acid and was not precipitated in the bed. Although iron in the form of ferric sulfate did not interfere with neutralization of free acid, hydrolysis of residual ferric sulfate caused an increase in the titratable acidity of effluent from the bed; some precipitation of ferric iron was brought about by the action of the limestone.

The process of application at a high rate of upward flow to a bed of small particles of limestone might be of value in reducing the acidity of waste waters from the pickling of steel, and would have the advantage that large volumes of waste water could be treated in a comparatively small plant.

H. P. ORLAND

Petroleum from Fermentation. *Science et Vie* (France), No. 382, p. 3 (July, 1949).

This is a report of the work done by Dr. Jean Laigret in Tunis. In the course of studies on methane fermentation, he came across *B. perfringens*, an anaerobic bacterium associated with gas gangrene and also known for the fermentation of organic matter with the production of carbon dioxide and hydrogen. This fermentation comes to a stop at the end of a few days, the liquid becoming acid. When ammonium formate is fermented by this organism, the fermentation is more regular and prolonged; the gas is more abundant, consisting of equal parts of carbon dioxide and hydrogen. Addition of a trace of potassium iodide (1:5000)

to the substrate containing ammonium formate, gave an initial fermentation similar to the series without potassium iodide. However, it came to a stop at the end of 10 to 15 days, after which there took place a second gas production containing a large percentage of methane, which had not been produced before. Various other organic materials, either containing or not containing cellulose, gave similar results. Apparently, the iodide acted as a catalyst. It was concluded that *B. perfringens*, without the aid of any other bacteria, is capable of bringing about methane fermentation, provided a catalyst aided the reaction. One gram of formate produced 1,600 ml. of gas, of which the first half contained 80 per cent hydrogen and the second half 80 per cent methane.

The second approach was to establish a relationship between methane fermentation and petroleum production, using the same organism (*B. perfringens*) under similar conditions, except that the substrate contained higher fatty acid (oleic acid). At first only carbon dioxide was obtained, but on the surface of the fermented material there was a black, combustible liquid immiscible with water. Analyses showed that this material could be classified as petroleum. On repetition on a continuous basis, the same results were obtained, with 3 ml. of petroleum being obtained per 4 grams of soap. It was concluded that petroleum could be produced by bacterial fermentation and that *B. perfringens* could produce not only methane, but also petroleum. It is possible that other bacteria also may play a part in the origin of petroleum deposits and that petroleum may have a mineral origin. Petroleum deposits generally are found near interior seas, in which very active biological synthesis takes place. The dead bodies of vegetable (including plankton) and animal materials sink to the bottom. Oxygen disappears from the bottom deposits and bacterial action takes place under anaerobic conditions; petroleum is produced. In petroleum bearing strata are found fossil and living anaerobic bacteria.

The products of fractional distillation of crude petroleum obtained from sewage sludge are as follows:

Distillation Temp. (°C.)	%	Type of Product
175	26	
175 to 280	21	Kerosene
280 to 310	21	Gas oil or fuel oil
Residue	22	Very heavy fraction

The experiments were conducted on a laboratory scale with small volumes. The fermentation is started by seeding the fermentible wastes with *B. perfringens* and the addition of small quantities of cheap chemicals.

Temperature has an important effect on the time required. Methane is produced below 30° C. The optimum temperature, however, is between 37° and 40° C. Above 43° C., the fermentation stops. All the experiments were made at normal atmospheric pressures. It is expected that at higher pressures better results might be obtained. The fermentation, after a variable period, gives equally variable products, according to the materials used for fermentation, but which consist of combustible gases and of liquid hydrocarbon. The composition of crude petroleum obtained by fermentation is practically the same from the different organic substrates fermented. With vegetable oils, 80 per cent is transformed to hydrocarbons, of which 65 per cent is in the form of crude petroleum and 15 per cent is gaseous hydrocarbons. One ton of oil fermented yields 800 l. of petroleum and 200 cubic meters of combustible gas. Waste oil cakes, non-edible bottom oils, and castor oil could be substituted for pure vegetable oils. Fish wastes produce 70 per cent of their weight as hydrocarbons. Citrus fruit pulp produces 37.5 per cent of its weight as hydrocarbons—187 l. of petroleum and 300 cubic meters of combustible gas per ton. Dead leaves might also be digested. Experiments were performed with the digestion of sewage sludge, from which 106 l. of crude petroleum and 124 cubic meters of gas was obtained per ton of sludge.

H. HEUKELEKIAN

Beet Sugar Waste Treatment. ANON. *Chem. and Eng. News*, **28**, 13, 1038 (Mar. 27, 1950).

This brief article, presented under the heading of Research Progress, describes a process for waste elimination and sugar recovery in connection with beet sugar manufacture. The method was developed

in the sanitary engineering laboratories at Massachusetts Institute of Technology and involves chlorination (25 to 65 p.p.m.) of the waste under controlled pH (5.5 to 7.0) conditions. After chlorination, coagulation, and sedimentation, the treated process waste water is suited for use as extraction water. The result is better sugar recovery and a decrease in water requirements. The small amount of sludge produced can be disposed of readily. Full-scale installations have been tested in Ohio and Michigan. Preliminary estimates indicate that the savings in sugar alone will pay for the cost of treatment.

PAUL D. HANEY

Pendray Outlines Waste Disposal Program. A STAFF REPORT. *Chem. and Eng. News*, **27**, 49, 3632 (Dec. 5, 1949).

This paper, presented by a member of the firm of Pendray and Leibert, deals principally with the important problem of public relations in connection with industrial waste air and water pollution. General observations, which may prove useful to other industries, are presented, as follows: (1) all new plants should have adequate smoke, fly-ash, etc. control; (2) make engineering studies of any existing air or water pollution studies and tell the community the whole story; (3) discuss the problem freely and present your story skillfully; and (4) have supporting facts, reasons, and explanations readily available if you believe your plant is being unjustly accused of air or water pollution.

PAUL D. HANEY

Underground Disposal of Process Waste Water. BY LAWRENCE K. CECIL. *Ind. Eng. Chem.*, **42**, 4, 594 (Apr., 1950).

The petroleum industry daily is disposing satisfactorily of millions of gallons of highly mineralized oil field brines into thousands of disposal wells. This method should be considered by any chemical industry having to dispose of a waste water that cannot be conditioned for disposal into the natural drainage. In some areas no suitable disposal formations exist, but wherever there is an appreciable depth of sedimentary deposits a study of the possibilities should be made. The technology of well completion has been adequately established by the petroleum industry, but care must be exercised in the selection of the disposal formation. Waste water must be treated so that it will not plug the face of the receiving formation.

This method of disposal has been used by several manufacturing plants associated with the petroleum industry. A report of 18 months of successful operation of a waste treating plant and the receiving well presents the problems associated with treatment and injection-well disposal of waste water.

PAUL D. HANEY

Neutralization of Acid Wastes. BY B. W. DICKERSON AND R. M. BROOKS. *Ind. Eng. Chem.*, **42**, 4, 599 (Apr., 1950).

A description is presented of an economical method of neutralizing an acid waste of variable quantity and quality. The results of waste neutralization are such that the effluent's effect on the receiving stream is negligible, thus eliminating a formerly serious source of pollution.

The acid wastes resulted from the manufacture of nitrocellulose and consisted principally of dilute water solutions of nitric and sulfuric acids. Neutralization is accomplished with a dolomitic lime. This type of lime was found to be the most economical and, fortunately, the best from a chemical standpoint. Neutralization is carried out in a multi-compartment reaction chamber and automatic pH control is provided.

The paper gives details of the preliminary investigations, engineering design, construction and operating problems and procedures.

PAUL D. HANEY

Operation of Anaerobic Fermentation Plants. BY ARTHUR M. BUSWELL. *Ind. Eng. Chem.*, **42**, 4, 605 (Apr., 1950).

The anaerobic process of digestion of organic matter yields a humus-like solid material and a gas composed of methane, carbon dioxide, and hydrogen. This process effectively accomplishes the stabilization of putrescible waste liquors; where conditions permit its use it is much cheaper per pound of organic matter stabilized than aerobic processes. The process has two serious limitations: (1) for unknown reasons it is impossible to produce an

effluent comparable to that given by aerobic treatment; and (2) the cost of the treatment increases as the concentration of the waste decreases.

The preferred design for an anaerobic fermentation plant consists of two to three floating cover digestion tanks arranged to operate in series. A heat exchanger is required for the maintenance of the desired temperature. Circulating pumps and suitable piping to permit various schemes of operation and circulation are necessary.

Anaerobic waste treatment plants treating wastes from various industries have been in operation for a number of years. B.O.D. removals from about 70 to 90 per cent have been obtained with tank loadings of from 0.10 to 0.14 lb. per cu. ft. per day. Gas production ranges from 5.0 to 11 cu. ft. per pound. It is believed that under carefully controlled conditions 90 per cent purification can be obtained with a tank loading of 0.143 lb. per cu. ft.

PAUL D. HANEY

Report of the Auckland Drainage Commission. BY R. H. QUILLIAM, T. B. NICOL, AND J. H. BARNETT. 67 pp. (1949).

This is a report of a Commission (appointed by the Governor-General) upon the treatment and disposal of sewage in the Auckland Metropolitan Drainage District. The area lies in two catchment areas draining to two harbors and Hauraki Gulf. One harbor has deep water, and with the Gulf is used for shipping, yachting, and recreation; the other is shallow, and lined with industry, with less recreation. There is considerable pollution from many outfalls. Since 1927, various projects have been considered. Prior to 1946, the opposition was based on the pollution factors; since 1946, on the failure to provide for composting the sewage solids to make humus.

The report considers the general factors, the utilization of sewage, and the disposal of sludge. The Commission had before it the Porter report. Apparently, objections were made by industry to paying charges. The Commission recommends that the Board should be given power by an amendment of the Drainage Act to fix the charges to be made to industry for the disposal of their wastes.

The utilization of sewage sludge is discussed with liberal quotations from FSWA "Manual No. 2." After pointing out Mr. Porter's preference for sludge digestion followed by air drying and rapid grounding at high temperatures, the Commission discusses the value of organic manure, noting that agricultural experts indicated the need of phosphate and the uneconomic status of composting. The Commission concluded that composting should not be made a part of the sewage scheme and that the cultivation of water plants is not warranted, because such procedures have not been demonstrated on a working scale and are full of risks. Further, the Commission considers it unwise for the Drainage Board to take up composting of municipal wastes. Oxidation ponds were also dismissed.

The Commission considers that the Drainage Board should produce an air-dried digested sludge, which can be used either as an activator in making compost or for conversion to heat-dried pulverized fertilizer. It also recommends that, in principle, the Board's alternative scheme be adopted as most suitable for the drainage of the Central and Southern Districts.

Amendments to the enabling act were also indicated, to broaden the scope and jurisdiction of the Board.

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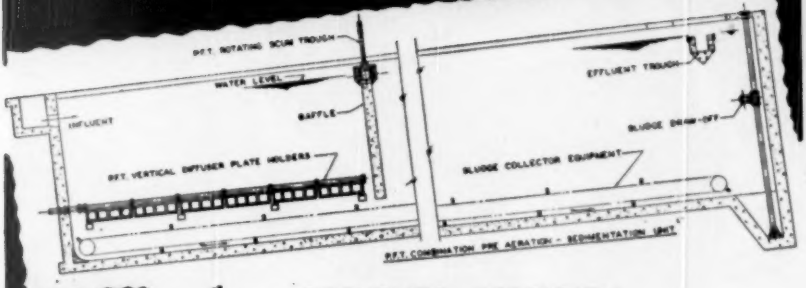

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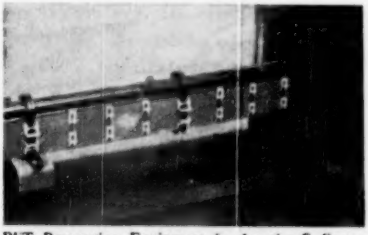

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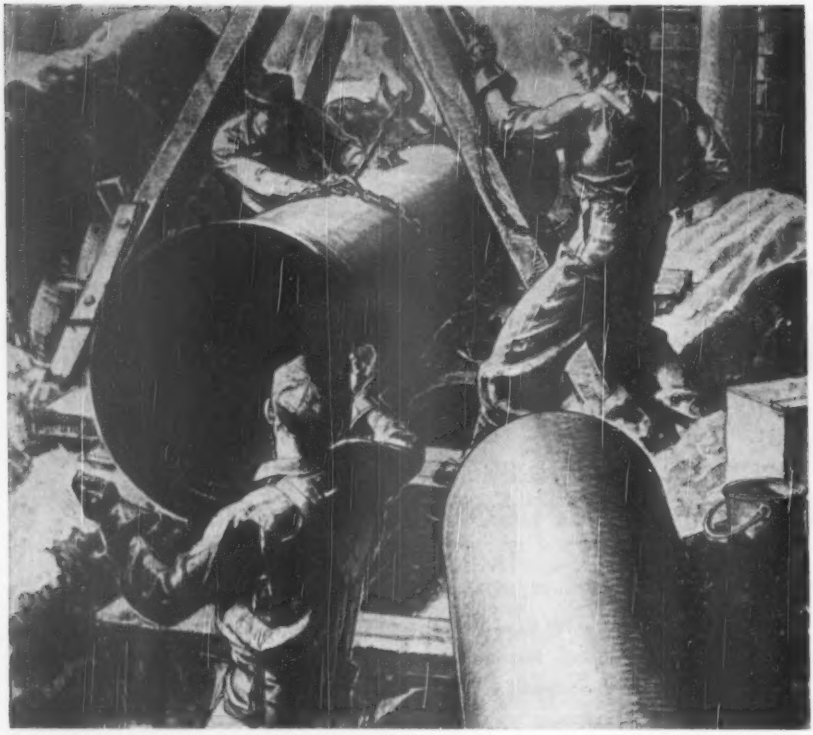

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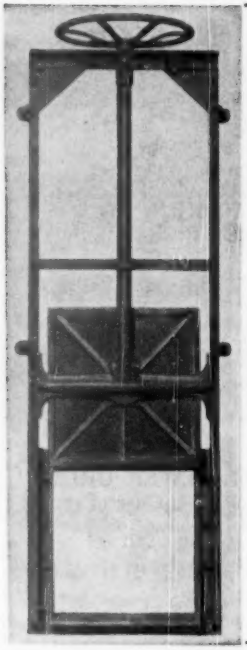

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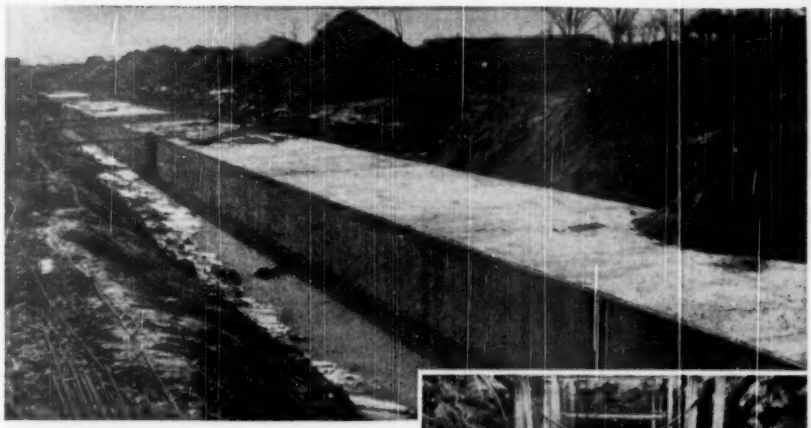

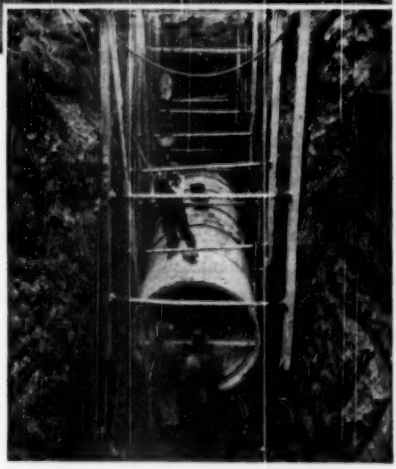

Upper photo shows completed section of reinforced concrete box sewer, 7 ft. high x 16 ft. wide, before backfilling. Lower photo shows 66-in. reinforced concrete pipe being placed in a 24-ft. cut.

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In addition, the system required over two miles of reinforced concrete sewer pipe, 18 in. to 78 in. in size.

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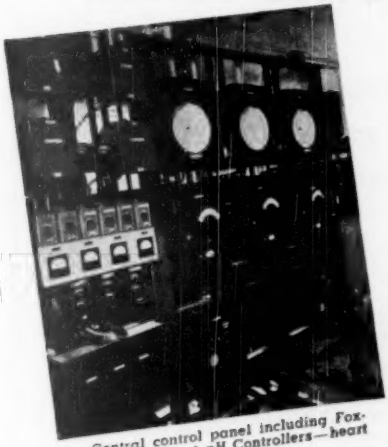

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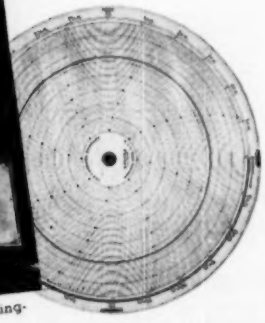
2. Waste treatment tanks at Westinghouse plant, Beaver, Pa.



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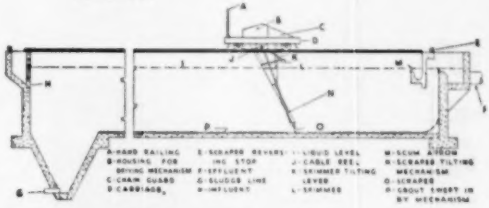

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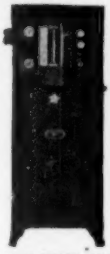

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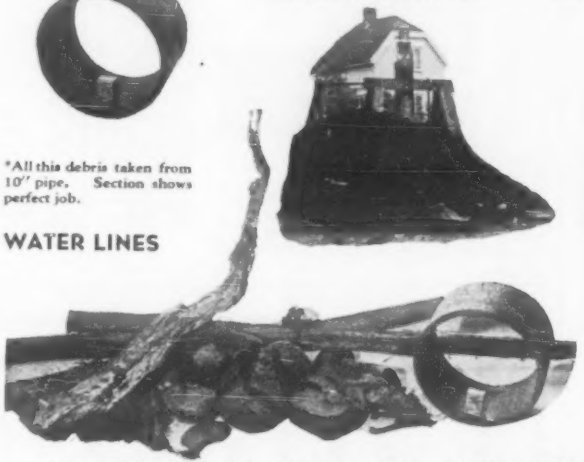

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